II. GENERAL DESCRIPTION OF THE *SCANIMATE* SYSTEM

2.1 System Capabilities

Scanimate has two basic functions: *animation* and *colorization*.

2.1.1 Animation

Under the control of an operator, *Scanimate* will pro-
duce animated sequences from a static, high contrast transparency
input or from a standard television signal input. The animated
sequences may be recorded directly onto black and white film by photo-
graphing a cathode ray tube (CRT) face on which the animation appears.

2.1.2 Colorization

If a colorized end product is desired, the animated
sequence from the CRT face can be entered into another portion of the
Scanimate system which, within certain limitations, will supply the
desired colors. The colorizer portion of *Scanimate* can also be used
to color or recolor standard television signals--again within certain
limitations. The colorized output from *Scanimate* is normally recorded
on video tape.

2.2 *Scanimate* Components
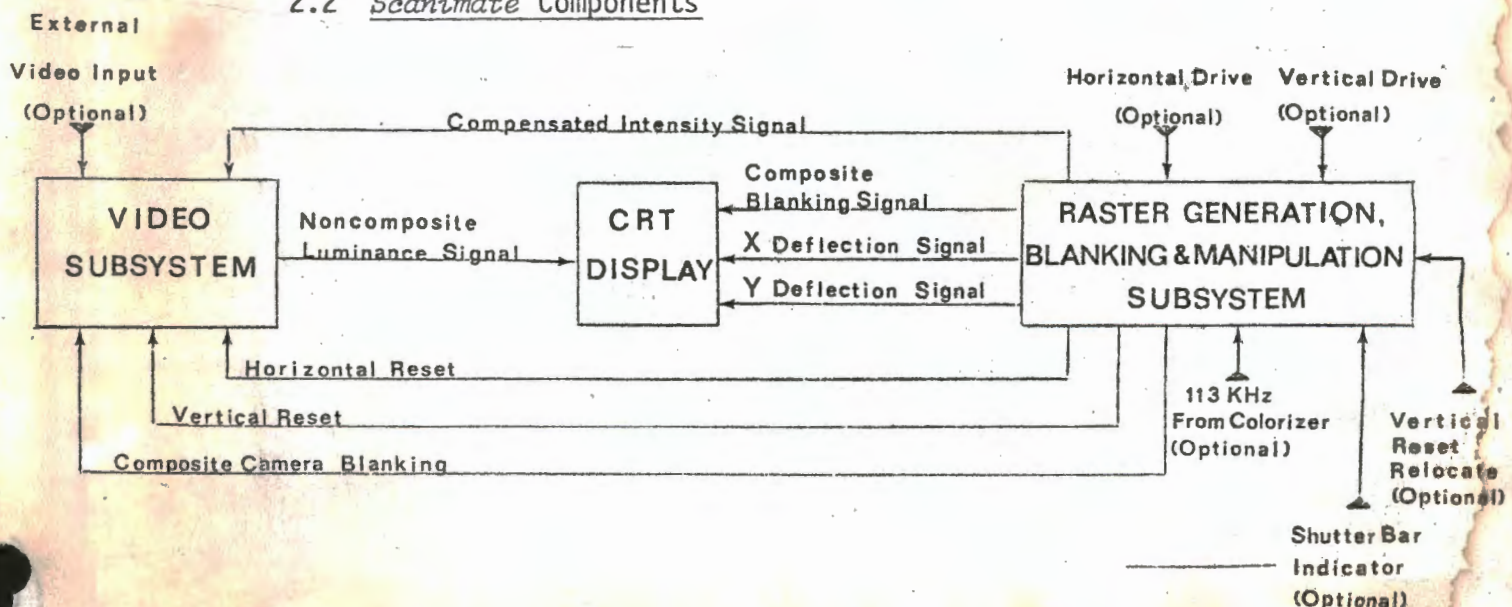
III. OPERATING MODES OF THE *SCANIMATE* SYSTEM

There are two modes in which *Scanimate* can be used to generate animated sequences. There are also two modes in which *Scanimate* can be used as a colorizer. The different modes of operation relate to different methods of supplying input data to *Scanimate*.

3.1 Animation Modes

Scanimate's ANIMATION SYSTEM can accept input data in the form of either a high contrast transparency or a standard television video signal.

3.1.1 High Contrast Transparency

If a transparency (also referred to as an *artwork*) is used, it is placed on top of a light box inside one of the *Scanimate* camera racks. The light which passes through the transparency is focused onto the target of a television camera tube. The output of the camera--a black and white, noncomposite video signal--controls the intensity of the animated raster of the *MONITOR CRT*. This CRT is the output device of the *Scanimate ANIMATION SYSTEM*.

3.1.2 Standard Television Signal

If a standard television signal is to be animated, the signal is first sent through circuits which remove its synchronization and color information and thereby turn it into a noncomposite, black and white video signal. This signal is then used to control the intensity of the animated raster in the same way as a video signal from the *Scanimate* camera.

3.2 Colorization Modes

The *COLORIZER SYSTEM* can separate the black and white video input signal into as many as five different shades of gray and assign a different color to each of the five gray levels. All parts of the input black and white picture which have the same brightness will have
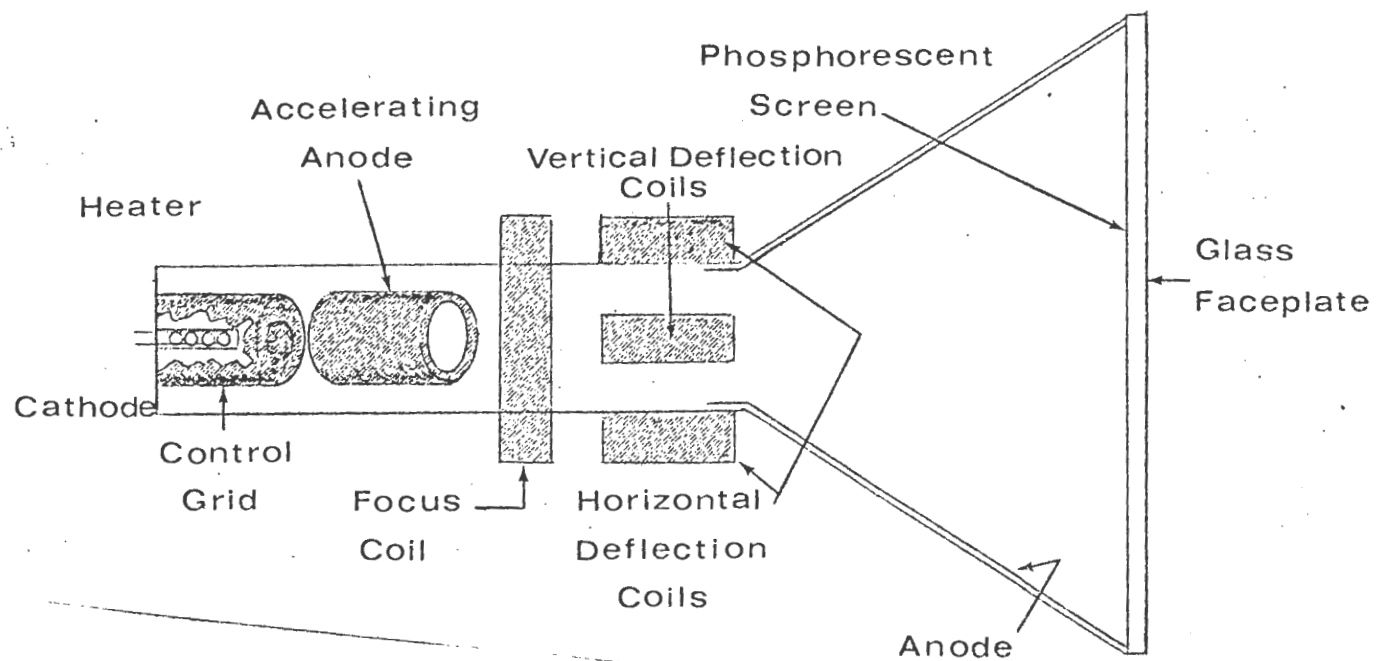
the same color in the output picture from the colorizer. It is
possible to have more than five colors present at the same time in a
scene colorized by *Scanimate*, but this process requires the use of
multiple-pass video tape recorder (VTR) techniques. The *COLORIZER
SYSTEM* of *Scanimate* accepts video input data either from the *SCAN-
CONVERTER CAMERA*, which is normally focused on the *MONITOR CRT*, or
from an external video source.

3.2.1 *SCAN-CONVERTER CAMERA* Input

If the animated image on the *MONITOR CRT* is to be
colorized, the noncomposite video input from the *SCAN-CONVERTER* is
used.

3.2.2 External Video Input

If an externally generated video signal is to be
colorized, that signal is applied to stripping circuits which turn it
into a noncomposite, black and white signal. The signal is then
colorized in the same way as a signal from the *SCAN-CONVERTER CAMERA*.

Heater

Accelerating
Anode

Vertical Deflection
Coils

Phosphorescent
Screen

Glass
Faceplate

Cathode

Control
Grid

Focus
Coil

Horizontal
Deflection
Coils

Anode

IV. THEORY OF OPERATION FOR THE *SCANIMATE* SYSTEM

Scanimate produces animation by manipulating the raster of a television display. The basic principles of television, especially the concept of a raster, must therefore be understood before the techniques used with *Scanimate* can be meaningfully explained. Let us begin by considering a familiar component of the television system: the picture tube.

4.1 Principles of Television

4.1.1 The Picture Tube

A typical picture tube is diagramed in Figure 4-1. The inside of the picture tube's face is coated with a phosphor that emits light when struck by a high velocity electron beam. The electrons for this beam are emitted from the *CATHODE* when it is warmed by the *HEATER*. The negative electrons are accelerated to a high velocity by large positive potentials on the *ACCELERATING ANODE* and the *ANODE*. Simultaneously, the electrons are formed into a beam by the *CONTROL GRID* and the *FOCUS COIL*.

The electron beam is only a few millimeters in diameter when it strikes the picture tube's screen; the beam, consequently, causes the screen to emit only a small point of light. The intensity of the emitted light is directly proportional to the number of electrons per second which strike the screen and is regulated by a signal applied

Figure 4-1

between the *CONTROL GRID* and the *CATHODE*. If there is no potential difference between the *CONTROL GRID* and the *CATHODE*, the maximum number of electrons will reach the screen. If the *CONTROL GRID* is made sufficiently negative relative to the *CATHODE*, no electrons will reach the screen; the beam is said to be *blanked*.

When the electron beam is blanked, the point on the phosphor where the beam was landing will continue to emit light for a short time. This characteristic of the phosphor is called *persistence* and plays a very important part in all television systems. The human eye has a similar and equally important characteristic which causes one to see light for a short time after the source has been extinguished. Because of these persistence tendencies, the entire television screen can be made to appear uniformly illuminated if the electron beam is made to move very rapidly over the area of the screen. *The pattern in which the beam is made to move over the screen is called the* raster.

4.1.2   The Standard Television Raster

The raster is the same in all major television systems. A simplified example of this standard raster is given in Figure 4-2. The solid lines with arrowheads on them represent the raster. The dashed lines with arrowheads on them represent the return path along which the electron beam would move between raster lines if it were not blocked. The spot moves at a constant velocity while tracing out the raster lines.
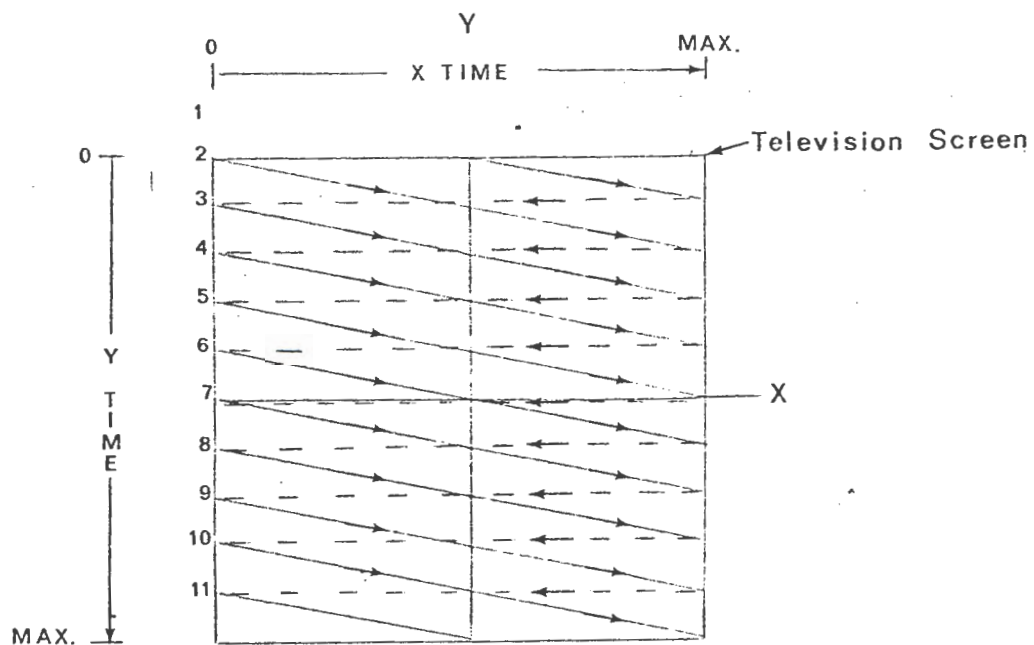
4.1.3 The Deflection of an Electron Beam in a Picture Tube

There are two common types of electron beam deflection: electrostatic deflection and electromagnetic deflection. The approach most often used in television systems, and used exclusively in *Scanimate*, is electromagnetic deflection.

The location of the coils of the electromagnets associated with a typical picture tube is shown in Figure 4-1.[1] There are two sets of electromagnets. One set can cause horizontal deflection; the other set, vertical deflection. By application of signals simultaneously to these two sets of coils, any combination of horizontal and vertical deflection can be achieved--the beam can be positioned at any point on the screen.

The beam will strike near the center of the screen when no signals are applied to the deflection coils because of the physical construction of the picture tube. When deflection signals are applied, *the displacement of the spot from the center of the tube's face will be directly proportional to the amplitudes of the deflection signals.* For example, let us assume that no signal is applied to the vertical deflection coils and that a signal with an amplitude of one unit is applied to the horizontal deflection coils. If this signal causes a spot displacement of one inch along the X-axis (see Figure 4-3a), then a signal with an amplitude of two units will cause the spot to be displaced two inches from center along the X-axis. If the sign of the horizontal deflection signal is reversed (-2 units), the spot will be deflected two inches in the opposite direction from the tube's center along the X-axis. The same applies to the vertical deflection signal and the position of the spot along the Y-axis. In Figure 4-3, the numbers in parentheses indicate the amplitudes of the deflection signals: (X amplitude, Y amplitude).

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[1]The location of the HORIZONTAL and VERTICAL DEFLECTION COILS may seem peculiar, the vertical coils located in the horizontal plane and vice versa. This orientation is necessary because the magnetic force on a charged particle moving through a magnetic field tends to accelerate the particle at an angle of 90° with respect to the field (Lorentz Force).

If we begin with line 1 in Figure 4-2 and trace out the raster, we find that the beam moves to the right and slightly downwards. The beam moves with a constant velocity; when it reaches the right side of the screen, it disappears (is blanked) for a short time and then reappears at the left side of line 3. The beam then moves at a constant velocity to the right and slightly downwards along line 3 until it again reaches the right side of the screen. Once more the beam is blanked for a short period of time and then reappears at the left side of the screen and begins tracing out line 5, etc.

When we get to the bottom of the screen we find that we have traced out all the odd numbered lines--one half of all the raster lines. At the end of line 11 the beam is blanked and then reappears at the beginning of line 2. Once again the beam traces down the screen but this time along the path indicated by the even numbered lines.

It follows that two vertical transitions down the screen are required to complete the raster. The portion of the raster drawn during each of the vertical sweeps is referred to as a *field*. The two fields together represent the smallest complete unit of picture information--the *frame* (one complete raster). The manner in which the lines of the two fields fall between each other is referred to as *interlace*. Interlace helps eliminate flicker and unnatural jerkiness of movement from the television display.

Perhaps at this point a consideration of the rates at which several actual television systems run will be of interest. In the United States, the National Television Systems Committee (NTSC) system is used. In this system the electron beam draws 60 fields (30 frames) per second, and each frame comprises 525 lines. In the English phase alternate line (PAL) system, 50 fields (25 frames) are drawn each second, and each frame comprises 625 lines. The animated raster of a *Scanimate* system designed for use in the NTSC system is typically drawn at the rate of 60 fields per second (30 frames) and 945 lines per frame.

The foregoing examples illustrate the diversity of rates at which the standard raster is drawn. In the next section we will consider how the electron beam is made to form the raster.
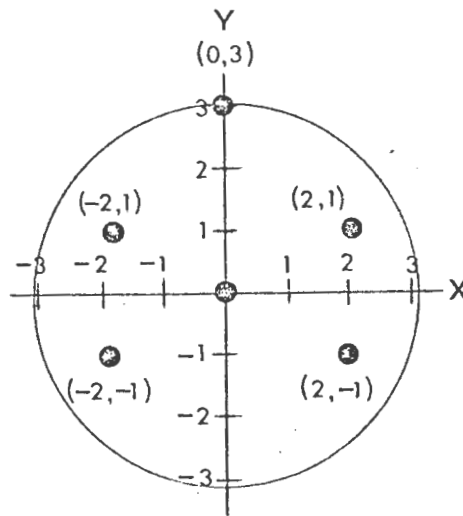
Figure 4-3b shows spot displacement for different values of horizontal and vertical deflection signals. As you can see, *the deflection of the beam along the X-axis follows the signal applied to the horizontal deflection coils, and the deflection along the Y-axis follows the signal applied to the vertical deflection coils.*

Keeping the preceding paragraph in mind, let us deduce the vertical and horizontal deflections required to generate the standard raster of Figure 4-2. Again assume that no vertical deflection signal is applied to the picture tube assembly; consequently the raster of Figure 4-2 reduces to the horizontal line shown in Figure 4-4.
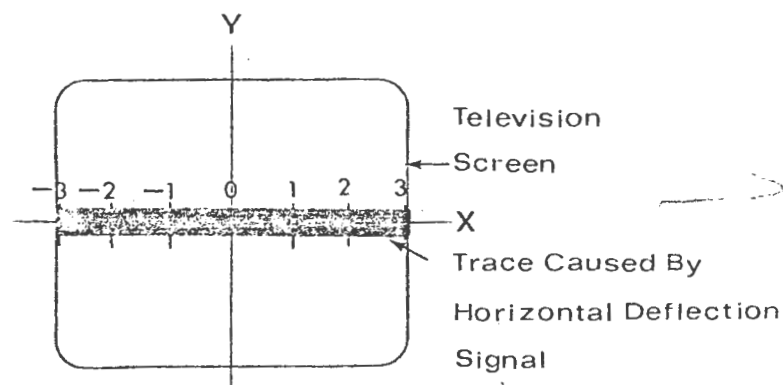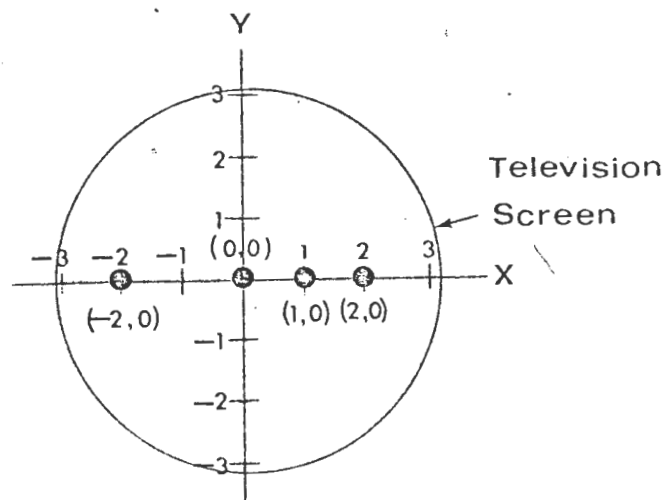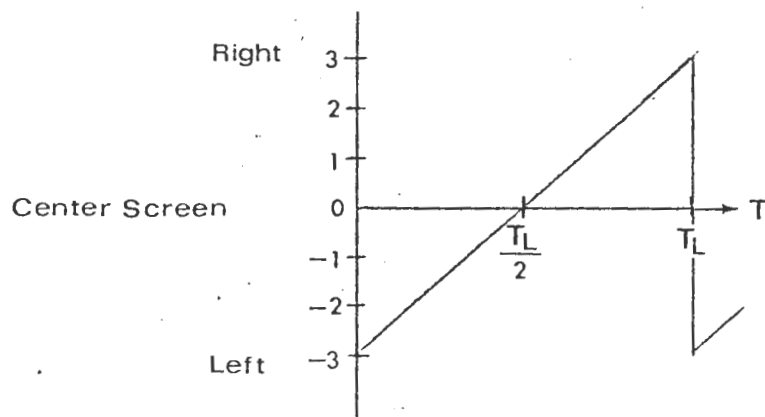
The spot moves periodically and at a constant velocity from the left side of the screen to the right as shown in Figure 4-5. When the spot reaches the right side of the screen, it is blanked for a very short time while the horizontal deflection signal is rapidly reset to its original level. When the blanking ends, the horizontal deflection signal again drives the spot across the screen.

From Figure 4-3 we know that when the spot is at the center of the screen, the input deflection signal will be of zero amplitude. We also know that deflection signals of equal magnitudes but opposite polarities will deflect the spot equal but opposite distances from the center of the screen. Since the spot must move linearly with respect to time and since the spot movement follows the deflection signal, the deflection signal must change linearly with respect to time. The deflection signal plotted against time must therefore be a straight line which passes through zero at its center.

Figure 4-6 shows the two possible forms of the deflection signal (notice the similarity between these signals and the graph in Figure 4-5). The two waveforms of Figure 4-6 are essentially the same, each being the inverse of the other. To simplify the following discussion, let us assume that the lower waveform gives us the desired left-to-right deflection.

T_L = The Time Required
To Draw One Line
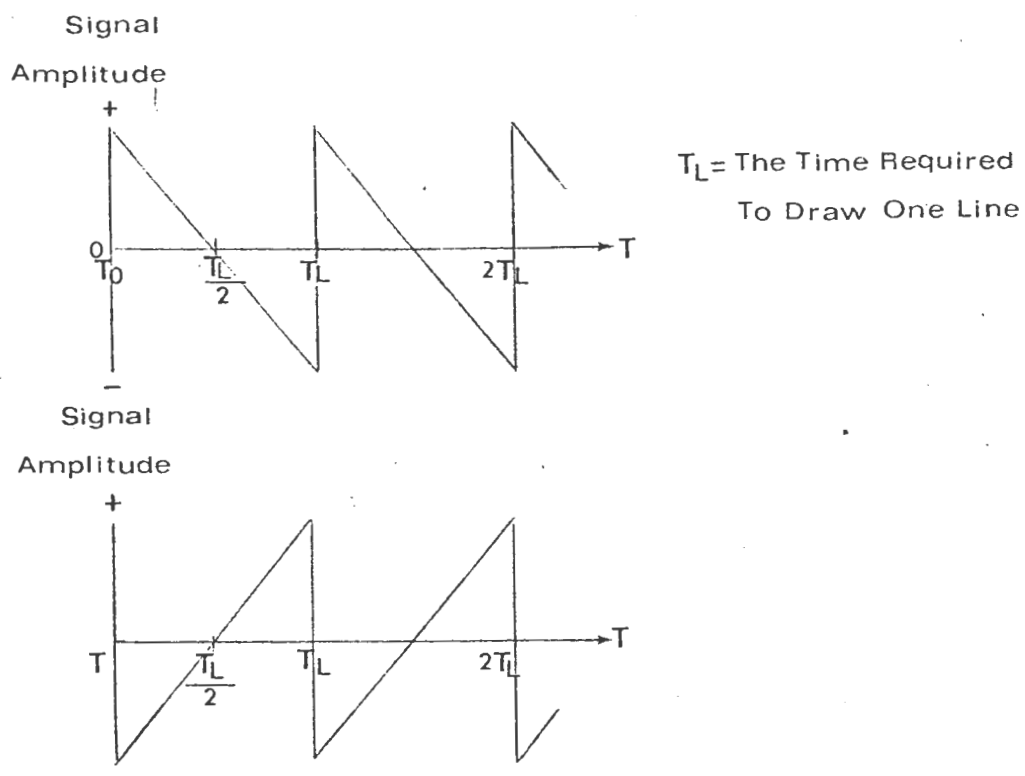
Initially, at time T_0, the deflection signal is of maximum negative amplitude and deflects the spot to the left side of the screen. The magnitude of the deflection signal decreases linearly to zero during the interval of T_0 to $(T_L)/2$, and the spot moves at a constant velocity to the center of the screen. After $(T_L)/2$ the polarity of the deflection signal is reversed, and its magnitude increases linearly with time until time T_L (the time required to draw one line). During the $(T_L)/2$ to T_L interval, the spot continues to move across the screen at the same constant velocity. At time T_L the deflection signal is at its maximum positive amplitude, and the spot is at the right side of the screen. At time T_L the electron beam is blanked for a short time while the deflection signal resets to its original negative value which forces the spot back to the left edge of the screen.[2] Either of the waveforms in Figure 4-6 could represent the X-deflection waveform.

If we look at the standard raster with the X-deflection reduced to zero (Figures 4-7 and 4-8), we see that the Y-deflection signal moves the spot at a constant velocity from the top of the screen to the bottom. When the spot reaches the bottom of the


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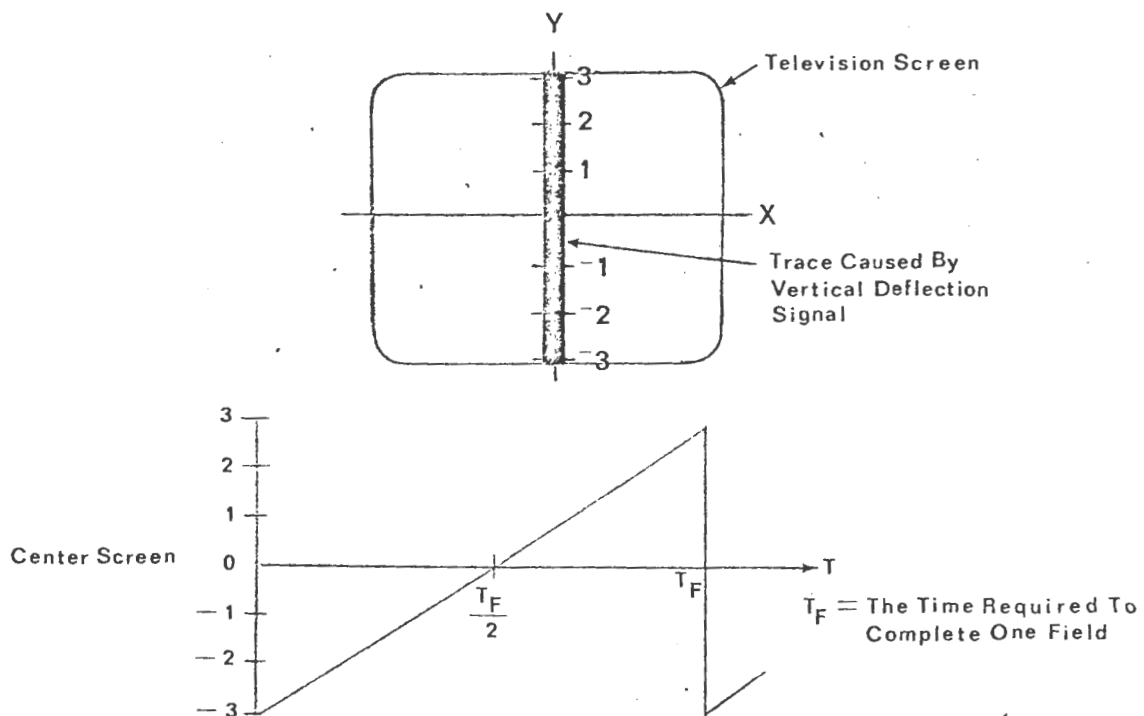
[2]To simplify the drawings, the reset interval is shown as being instantaneous. Actually it is not.

screen, the beam is blanked for a short time to prevent the reset of the vertical deflection signal from being seen. The spot then re-appears at the top of the screen and starts tracing down again. This process is the same type of movement that the horizontal component of the raster had. Therefore, the required vertical deflection can be generated by applying a waveform similar to the horizontal deflection waveform to the vertical deflection circuits. The essential difference between the two waveforms is frequency--the frequency of the vertical deflection waveform must equal the field rate of the raster (50 Hz or 60 Hz), and the frequency of the horizontal deflection waveform must equal the line rate (greater than 15,000 Hz). The two deflection wave-forms applied to the appropriate deflection coils in the appropriate manner result in a standard raster.

4.1.4 Modulating the Luminance of the Picture Tube's Raster

In the preceding paragraphs we have defined the standard raster and described the type of deflection signals needed to generate the raster, but so far we have considered only rasters of uniform intensity. In this section we will investigate how black and white images can be produced on the picture tube screen.

We already know that the intensity of light emitted from a particular point on the screen is directly proportional to the amount of beam current striking that point and the beam current is determined by the voltage between the picture tube's grid and cathode (Figure 4-9). By correctly varying the voltage between the *CONTROL GRID*
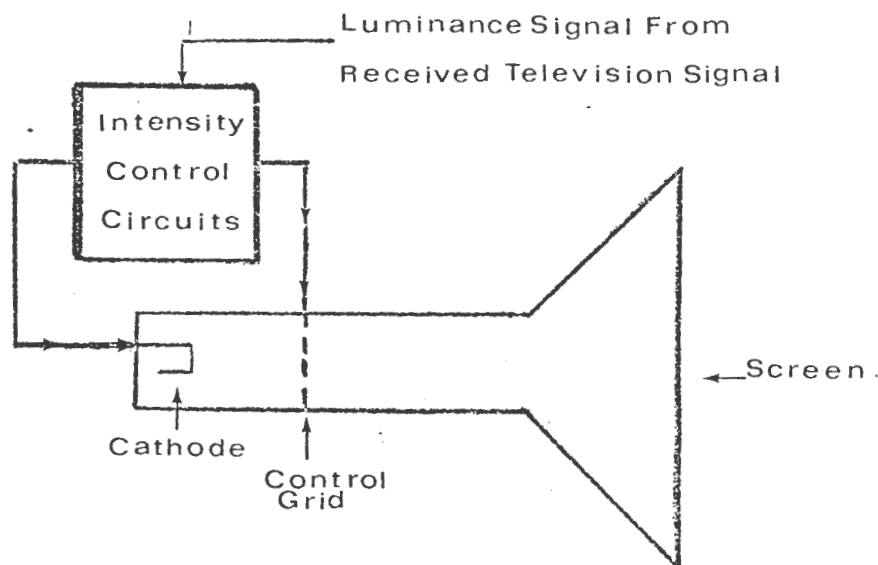
and the *CATHODE*, black and white patterns or images can be produced on the screen.

A normal television signal consists in part of *luminance information* which represents the various shades of gray in the picture being transmitted. At the receiver this information is separated from the rest of the television signal and is used to control the voltage between the *CONTROL GRID* and *CATHODE*.

4.1.5 The Television Camera Tube

The purpose of a television camera tube is to produce a luminance signal to control the intensification of a receiver's raster. Naturally, the luminance signal from the camera tube must accurately represent the shade of gray at each point in the scene on which the camera is focused.

There are two types of camera tubes used in *Scanimate*, vidicons and plumbicons. These tubes are similar in operation and construction, and the comments which follow apply to both.

Figure 4-10 shows a side view of part of the camera tube. Light from the scene on which the camera is focused enters the tube through the *GLASS TUBE FACE*, passes through the *TRANSPARENT CONDUCTING MATERIAL*, and strikes the *PHOTOCONDUCTIVE MATERIAL*. The *TRANSPARENT CONDUCTING MATERIAL* is externally connected to a positive potential, and the current from the conducting layer constitutes the output of the tube.
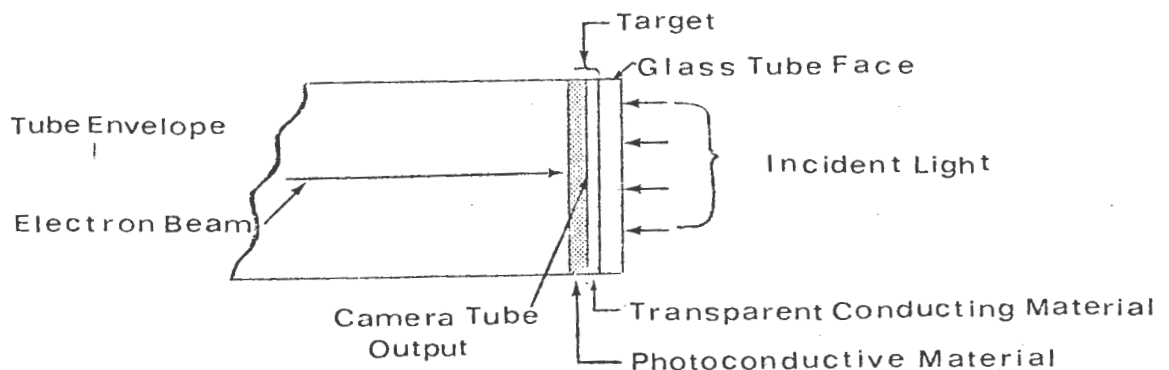
Using the same techniques as in the picture tube, an
ELECTRON BEAM is generated in the camera tube and deflected in the
standard raster format across the back of the *PHOTOCONDUCTIVE MATERIAL*.
The resistance between each point on the back of the *PHOTOCONDUCTIVE*
MATERIAL and the conducting layer depends on the intensity of the light
striking the *PHOTOCONDUCTIVE MATERIAL* at the given point. If the point
is brightly lit, the resistance of the *PHOTOCONDUCTIVE MATERIAL* will be
relatively low; if the point is dark, the resistance will be high.
Since the beam current through the photoconductive layer and out of the
TARGET is determined by the resistance of the *PHOTOCONDUCTIVE MATERIAL*,
the output of the camera tube is a *luminance signal*--a signal which
is directly related to the brightness of the light image at each point
on the *TARGET* of the camera tube.

4.1.6 Requirements for a Television System

We will now consider the relationship between the
television transmitter and the receiver to discover some of the
characteristics that a television system and the television signal--
the only link between the transmitter and the receiver--must have.

Let's assume that a television camera is focused on
a white square on a black background. The image of this artwork will
be formed on the target of the camera tube and scanned by the tube's
electron beam (Figure 4-11a). During the first 150 scan lines the
electron beam sees an all black target, and the output signal from the
target is minimum (Figure 4-11b).[3] For scan lines 151-450, the
electron beam sees black at the edges of the target and white in the
center; the output from the target, therefore, switches between
minimum and maximum. For scan lines 451-600 the electron beam again
sees an all black target and the output from the camera tube is again
minimum.

What is necessary to reconstruct the image of Figure
4-11a at the receiver? First, the luminance signal supplied by the

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[3]For simplicity a standard raster with a vertical frequency of 50 Hz
and a horizontal frequency of 15 KHz has been assumed. Therefore, the
time required to complete one field is 20 ms (period = 1/frequency), and
the time required to complete one line is approximately 66.7 μs. Another
consequence of the horizontal and vertical rates chosen is that each
field contains 300 lines; each frame, 600 lines.

Direction Of
Horizontal Scan

$T_L/4$ $3T_L/4$ $T_L \cong 66.7\,us$

Direction Of
Vertical Scan

Scan Lines 1-150

Scan Lines 151-450

Scan Lines 451-600

T_F

$T_F \cong 20\,ms$

MAX.

Luminance
Signal
Amplitude

MAX.

$T_L/4$ $3T_L/4$ T_L

Scan Lines 1-150
And 451-600

Scan Lines 151-450
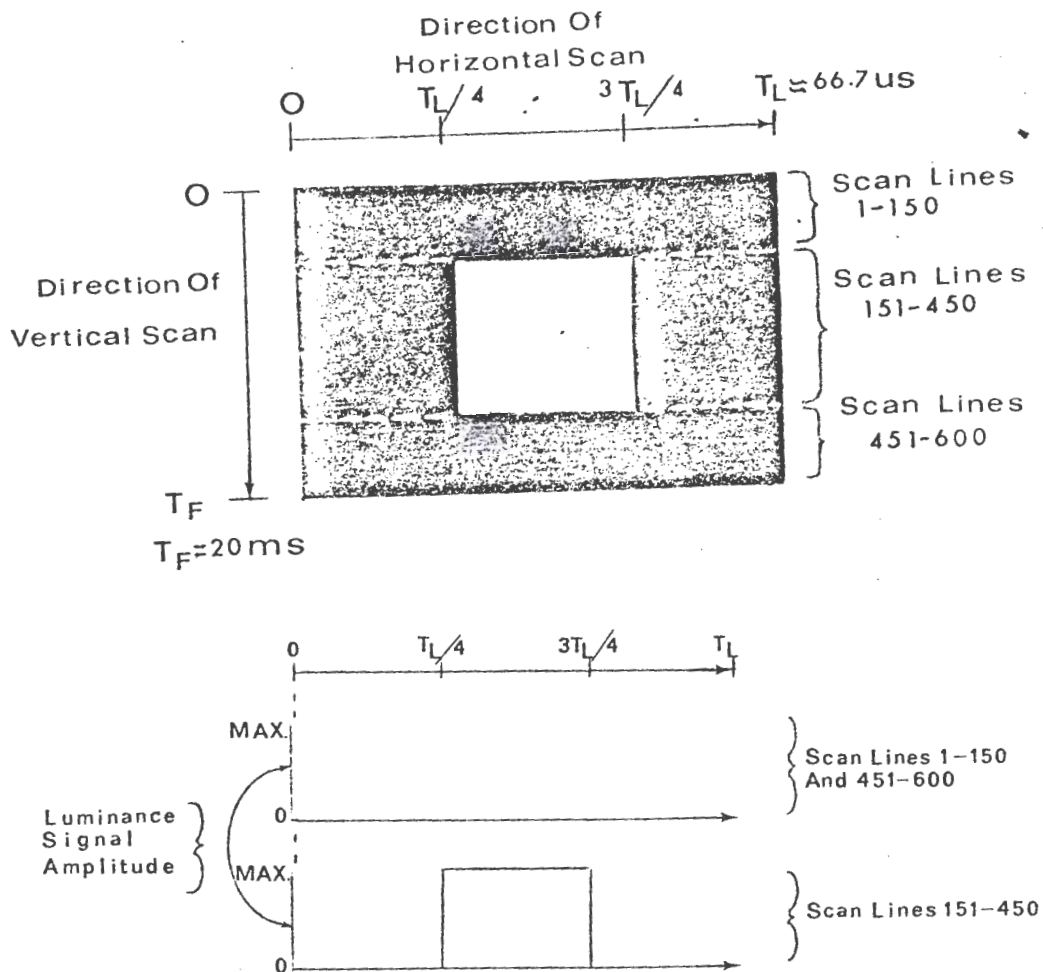
target of the camera tube is needed. Second, the relationship between
the receiver's raster and the luminance signal must be the same as the
relationship between the camera's raster and the luminance signal. The
validity of this second requirement is demonstrated by examples contained
in the following paragraphs.

Suppose we have a receiver and a camera that run at
the same vertical rate but different horizontal rates such that the
receiver takes twice as long as the camera to complete one line. If
at the beginning of each field both rasters bear the same relationship
to the luminance signal, the receiver will produce the picture shown
in Figure 4-12.[4] This picture is obviously not an accurate representation

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[4]Because of interlace, the luminance signal for the receiver's top
scan line corresponds to the luminance signals for scan lines 1 and 3
of the camera; the luminance signal for the receiver's second scan line
corresponds to the luminance signals for the camera's second and fourth
scan lines.

Direction Of Horizontal Scan

0   T_L $2T_L$

Direction Of Vertical Scan

T_F

Receiver Scan

Lines 1-300
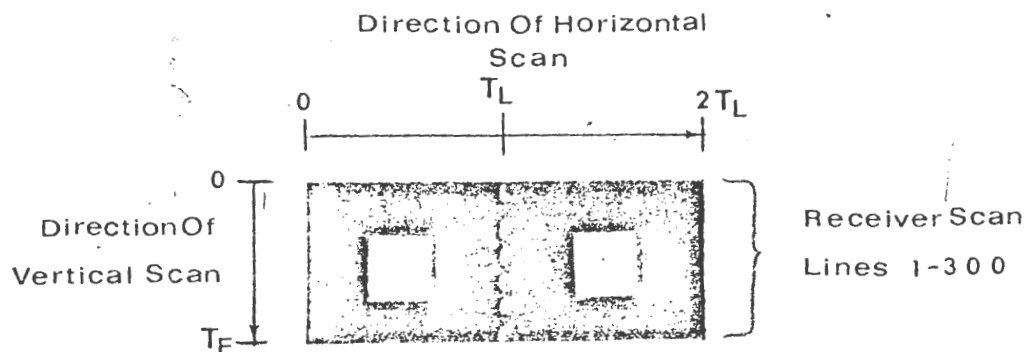
of the artwork seen by the camera, but if the receiver's line rate were doubled, the correct picture would be obtained.

If we make the same assumption that we made in the previous paragraph about the starting relationship of the rasters and the luminance signal, but this time assume that the line rates of the two rasters are the same and the field rate of the receiver is one half that of the camera, then the receiver will produce the picture shown in Figure 4-13. Again, the picture on the receiver is not the

Direction of Horizontal Scan

T_L

T_F

Direction of Vertical Scan

$2T_F$

The intensification of this part of the Receiver's Raster is controlled by the Luminance Signal developed from the Camera's odd numbered scan lines.

The intensification of this part of the Receiver's Raster is controlled by the Luminance Signal developed from the Camera's even numbered scan lines.

same as the image on the camera tube. The picture could be corrected
by doubling the receiver's field rate.

From the previous two examples we know that the rasters
of the camera and receiver must run at the same horizontal and vertical
rates to eliminate picture distortion. Figure 4-14 shows what happens
when the rasters do run at the same rates with the receiver's raster
advanced one half field with respect to. the camera's luminance-signal-
to-raster relationship. The distortion in this picture could be
eliminated by synchronizing the start of the receiver's vertical
deflection signal with the first line of luminance data in each field
of information received from the camera.

Direction of Horizontal Scan

0 $T_L/4$ $3T_L/4$ T_L

Lines 1 thru 150 of the receiver's raster correspond
to lines 301-450 of the camera's raster

Lines 151-300 of the receiver's raster correspond to
lines 451-600 of the camera's raster

Lines 301-450 of the receiver's raster correspond to
lines 1-150 of the camera's raster

Lines 451-600 of the receiver's raster correspond to
lines 151-300 of the camera's raster

Even if this were done, we could still get the kind
of picture shift shown in Figure 4-15. This distortion is caused by
the horizontal lines of the receiver starting 10 µs later than the
horizontal lines of the camera relative to the luminance signal. This
shift can be eliminated by synchronizing the start of the horizontal
deflection signal in the receiver with the beginning of each line of
luminance information in the incoming signal.

Direction of Horizontal Scan

0   T$_L$/4−10us   3T$_L$/4−10us   T$_L$

0

1 of
Scan

T$_F$

Lines 1–600 of the receiver's raster correspond
to lines 1–600 of the camera's raster
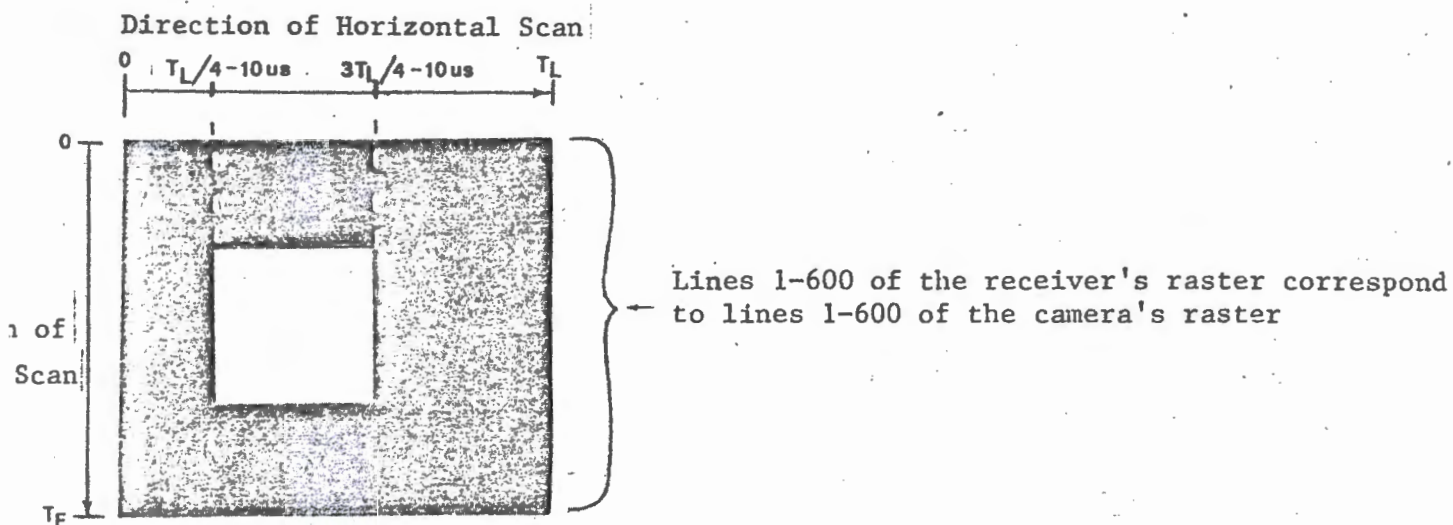
To summarize, the television camera and receiver must
have the same horizontal and vertical deflection frequencies. The
transmitted television signal must contain luminance information and
synchronization information which can be used to establish the same
relationship between the luminance signal and the receiver's raster
as between the luminance signal and the camera's raster.

4.1.7 Television Signals Used in *Scanimate*

Since *Scanimate* contains a large amount of television
circuits, the *Scanimate* operator needs to know how the different
television signals should appear in order to make necessary adjustments
and detect malfunctions in the equipment. To simplify the following
discussion and make it more explicit, we will assume that we are working
with an NTSC version of *Scanimate*.

4.1.7.1 Nonstandard *Scanimate* Television Signals

The television circuits contained in *Scanimate's*
ANIMATION SYSTEM are capable of running at nonstandard (noncommercial)

rates. Specifically, *Scanimate* has the same field rate (60 Hz) as a standard NTSC signal; the line rate in *Scanimate*, however, can be almost twice the standard rate (28.35 KHz instead of 15.75 KHz).

The nonstandard *Scanimate* television signal is also a *noncomposite signal--a signal which does not contain any synchronization information*. A noncomposite video signal can be used in *Scanimate* because the camera and the CRT (picture tube) are located close enough to each other to allow the same vertical and horizontal synchronization signals to be hard-wired to the deflection circuits of each unit. The *vertical reset* signal simultaneously forces all vertical deflection circuits to begin a new field, and the *horizontal reset* signal simultaneously forces all horizontal deflection circuits to begin a new line; the rasters are thus synchronized with each other. Since the time delay between the generation of the luminance signal at the camera and the application of that signal to the grid-cathode circuit of the CRT is negligible, all the rasters bear the same relationship to the luminance signal.

Since the horizontal deflection circuits operate at 28.35 KHz, the time taken to complete one line of scan is approximately 35.2 μs (Figure 4-16). Approximately 3 μs of this time, starting with the leading edge of the horizontal reset, are taken to reset the horizontal deflection circuits. To ensure that the flyback of the spot will not be visible on the CRT, the CRT's beam is blanked shortly before the horizontal ramp is reset and remains blanked during the entire reset interval. The CRT blanking continues for approximately 5 μs after the end of horizontal reset. During this interval the horizontal deflection ramps to the CRT and camera and the luminance signal output from the camera have time to stabilize before the CRT is intensified. The luminance signal produced from an all white input to the camera is shown in Figure 4-16. No luminance signal (black) is produced during this interval, even though the camera receives an all white input, because the camera's beam current is inhibited during the camera-blanking interval.

An analogous situation to the one described in the preceding paragraph exists among the luminance signal, vertical reset, the vertical ramp, and blanking. The vertical reset pulse is

Timing diagram showing waveforms versus time T, with markers at 0, 3us, 7us, 35.2us, 38.2us, 42.2us:

- **Horizontal Reset** — 24V / 0V
- **Horizontal Deflection Signal To Either The CRT Or The Camera** — +5V, 0V, −5V
- **CRT Blanking** — 36V / 0V
- **Camera Blanking** — 36V / 0V
- **Luminance Signal Output From The Camera (Luminance Signal Input To The CRT)** — White 1V / Black 0V

FIGURE 15   4-17

HORIZONTAL RESET

HORIZONTAL DEFLECTION SIGNAL

SCAN-CONVERTER CAMERA BLANKING

SCAN-CONVERTER CAMERA OUTPUT FOR AN ALL WHITE CRT SCREEN

Line Rate

Important video system signals and relationships within the Scan Converter Colorizer System

FIGURE 16   4-18

SCAN RATE OUTPUT FOR AN ALL-WHITE INPUT SIGNAL

SYNC TIP

0V
—10V
DEFLECTION SIGNAL

36V
0V
SCAN-CONVERTER CAMERA BLANKING

WHITE 1V
BLACK 0V
SCAN-CONVERTER CAMERA OUTPUT FOR AN ALL-WHITE CRT ...

Line Rate
Important video System Signals and Relationships within the Scan converter coloriger System

FIGURE 16   4-18

(a) 0 10.2µs   63.5µs 73.7µs   T

WHITE .7V
BLACK 0V
—.7V
SYNC TIP

SCAN RATE OUTPUT FOR AN ALL-WHITE INPUT SIGNAL

(b) See Below

The NTSC Black and White Signal
SYNC TIP — resets the horizontal deflection circuits in the receiver.

three lines long, however, and the vertical blanking signal, which
starts with the leading edge of the vertical reset, is adjustable
between 300 μs and 1 ms.

4.1.7.2   Standard *Scanimate* Television Signals

4.1.7.2.1   Black and White Signals

If the animated output of
Scanimate is to be recorded onto video tape for commercial purposes,
it must be changed into an NTSC video signal. This is done in part
by *scan-conversion--looking at the animated raster of the 'CRT with
a television camera that runs at NTSC rates*. This technique produces
an NTSC rate luminance signal from the animated raster. As Figure 4-17
shows, a different horizontal reset pulse must be fed into the *SCAN-
CONVERTER CAMERA* because its line period must be 63.5 μs.

The video signal of Figure 4-17
is still a noncomposite signal. Before the signal can be recorded
onto video tape, vertical and horizontal synchronization information
must be added to it. Figure 4-18a shows a typical line of the com-
posite NTSC black and white signal generated by *Scanimate* for an all
white input. *SYNC TIP* resets the horizontal deflection circuits in
the receiver. Figure 4-18b shows how *Scanimate's* composit output
looks during the vertical reset interval.

4.1.7.2.2 Color Signals

If the *Scanimate COLORIZER SYSTEM* is set up to colorize an input luminance signal, the luminance signal output from *Scanimate* will be covered with high frequency oscillations as shown in Figure 4-19. These oscillations, including the burst, are
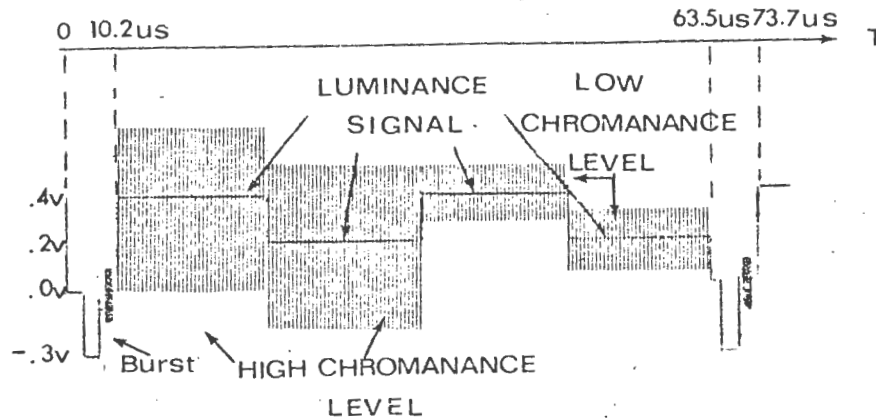
all of the same frequency and are referred to as the *chromanance signal*. The ratio of the peak amplitude of the chromance signal to the amplitude of the luminance signal at each point along the line determines the *saturation* (purity) of color at that point. For example, the first 0.4 V segment of luminance signal contains more color than the second 0.4 V segment, which would be diluted with white and appear washed out. The phase of the chromanance signal relative to the phase of burst at any point along the line determines the *hue* (color) of the picture at that point. If the chromanance signal were in phase with burst, the hue would be yellow with a little green; if the chromanance signal were 180° out of phase with burst, the hue would be blue with a little magenta. The luminance signal controls the brightness of the color: If green were the only color in Figure 4-19, the segments of the line with the 0.4 V luminance signal would appear brighter green than the rest of the line.

4.2 Principles of *Scanimate* Animation

Chapter III stated that *Scanimate* produces animation by manipulating the raster of a television display. Now that we know what a raster is and understand the relationships among the luminance signal and the rasters of the camera and the receiver, let us investigate a few of the animations which *Scanimate* can produce to see how the raster is actually modified.

4.2.1 Animations Modifying the Aspect Ratio of the Display Raster

One characteristic of the standard raster which we have not discussed is the *aspect ratio--the ratio of the raster's horizontal dimension (width) to its vertical dimension (length)*. The aspect ratio for commercial television is 4/3 (see Figure 4-20) and is a function of the amplitudes of the horizontal and vertical deflection waveforms which generate the raster. For example, if we assume that horizontal and vertical deflection signals of equal amplitudes cause equal displacements along the X- and Y-axes of a picture tube, then the ratio of the amplitude of the horizontal deflection signal to the amplitude of the vertical deflection signal must equal 4/3 in order to generate a raster with a 4/3 aspect ratio.

All of the rasters associated with *Scanimate* (i.e., the rasters of the *ARTWORK CAMERAS*, the *CRT*, the *SCAN-CONVERTER CAMERA*, and the *BLACK AND WHITE* and *COLOR MONITORS*) normally have 4/3 aspect ratios. *The only raster that is modified by animation, and therefore the only raster whose aspect ratio is subject to change, is the raster of the CRT.*
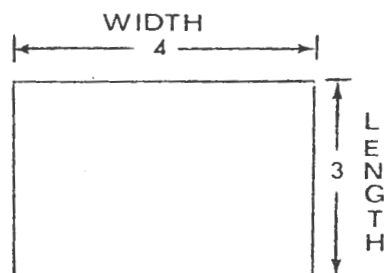
$$\text{ASPECT RATIO} = \frac{\text{Width}}{\text{Length}} = \frac{4}{3}$$

4.2.1.1 Width Animations

The amplitude and phase of the horizontal deflection waveform going to the CRT are easily controllable during animation. Suppose that we wanted to animate the output of one of the *ARTWORK CAMERAS* and that the image on the target of the camera tube were as shown in Figure 4-21. Figure 4-22 shows what happens as the horizontal deflection ramp to the CRT gradually has its amplitude reduced to zero, its phase reversed, and its amplitude returned to the initial value.

As you can see in Figure 4-22a&b, when the amplitude of the horizontal waveform is halved, then the width of the raster is also halved; since the length of the raster remains the same, the aspect ratio of the display decreases to 2/3. The decreasing aspect ratio makes the diagonal white area of the display rise more and more sharply until it becomes vertical when the amplitude of the horizontal deflection signal equals zero (Figure 4-22c). As the amplitude of the horizontal deflection signal increases in Figure 4-22d&e, the aspect ratio of the display also increases; the diagonal white area of the display returns to its initial angle of rise.

Figure 4-22d&e are mirror images of 4-22a&b and of the image on the camera tube's face (Figure 4-21). The reversal of the image in 4-22d&e is due to the phase inversion of the horizontal deflection signal. This phase inversion causes the horizontal lines of the CRT's raster to be drawn from right to left instead of from left to right as in the camera's raster. The relationship between the *ARTWORK CAMERA* and the *CRT* is such that the amount of light at each point on the camera's raster controls the intensity of each corresponding point on the CRT.[5] Since in Figure 4-22d&e the horizontal raster lines of the CRT are drawn in the opposite direction from the horizontal lines of the camera's raster, a point one third of the way in from the left edge of the camera's raster corresponds to a point one third of the way in from the right edge of the CRT's raster, etc. Consequently the image of the face of the CRT is reversed left-to-right from the image on the face of the camera tube.

---

[5]Review part 4.1.7.1 if you do not recall why this is so.

4.2 Principles of *Scanimate* Animation

Direction Of Horizontal Scan

0    $T_L/4$ $3T_L/4$

Direction Of
Vertical Scan

0
$\dfrac{T_F}{4}$

$\dfrac{3T_F}{4}$

T_F

3

4
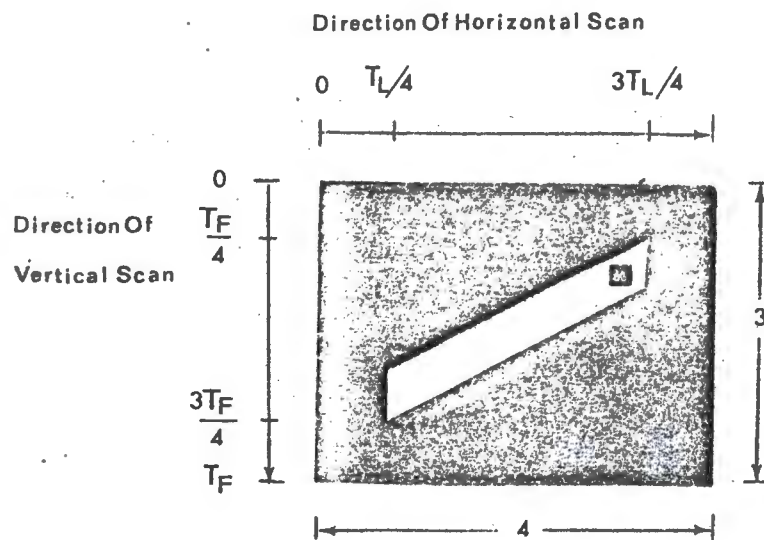
T_L = The Time Required To Draw One Line

T_F = The Time Required To Draw One Field

Direction Of Horizontal Scan

ction Of
tical Scan

4

3

2

3

(No Horizontal Scan)

Direction Of
Vertical Scan

3

AMPLITUDE

+A

0

T_L

-A

AMPLITUDE

$+\dfrac{A}{2}$

0

$-\dfrac{A}{2}$

T_L

AMPLITUDE

0

T_L

Horizontal Scan

Direction Of Vertical Scan

Amplitude

$+\frac{A}{2}$

0

$-\frac{A}{2}$

T_L

T

Amplitude

$+A$

0

$-A$

T_L

T

Direction Of Horizontal Scan

Direction Of Vertical Scan

Amplitude

$+A$

0

$-A$

T_F

T

Amplitude

$+\frac{A}{2}$

0

$-\frac{A}{2}$

T_F

T

Direction Of Vertical Scan

Direction Of Horizontal Scan
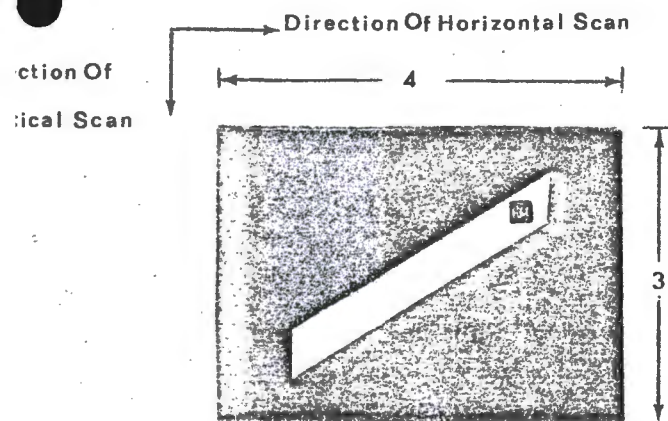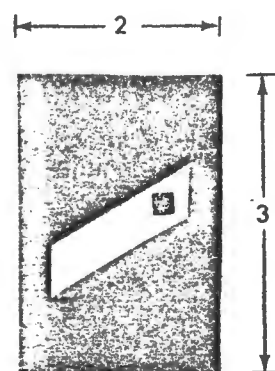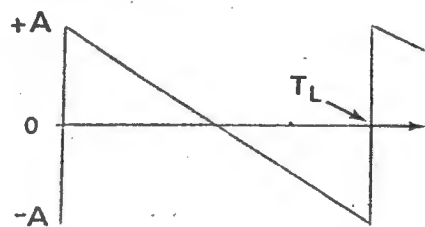
(No Vertical Scan)
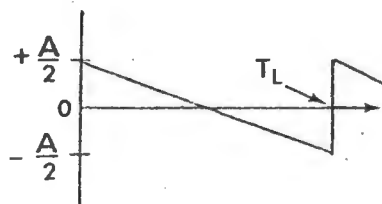
Direction Of Horizontal Scan

Amplitude
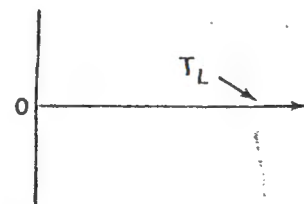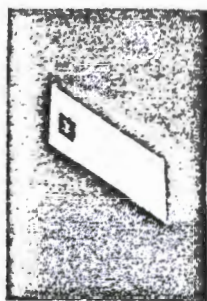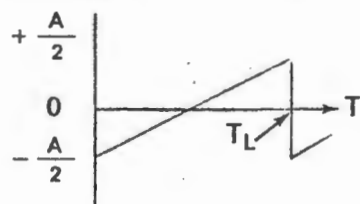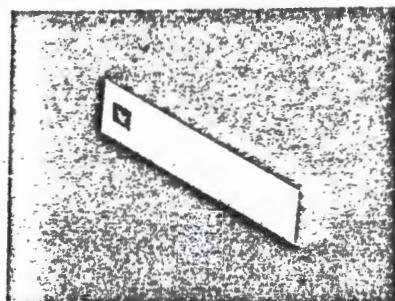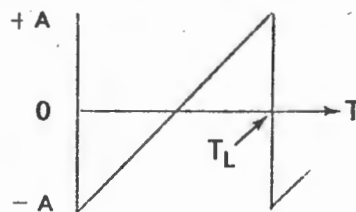
0

T_F

T

Amplitude

$+\frac{A}{2}$

0

$-A$

T_F

T
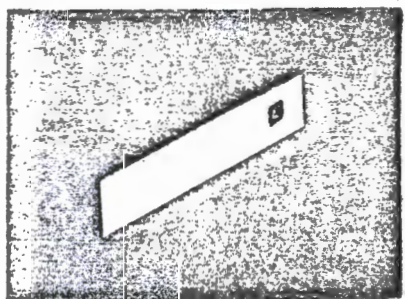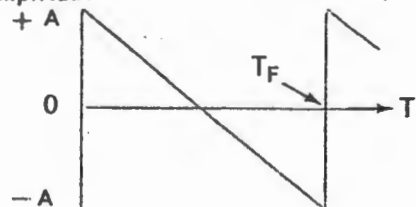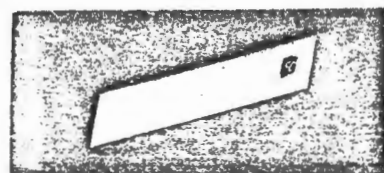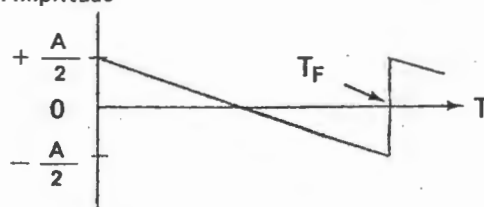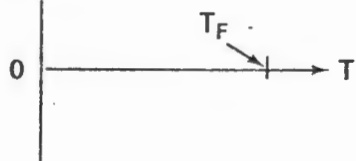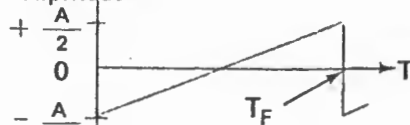
4.2.1.2 Length Animations

The amplitude and phase of the CRT's vertical deflection waveform are also easily varied during animation. The height of the CRT display is directly proportional to the amplitude of the vertical deflection signal. The CRT display can be inverted top-to-bottom by reversing the phase of the vertical deflection waveform.

Figure 4-23 shows what happens to the image coming from the camera (Figure 4-21) as the amplitude and phase of the
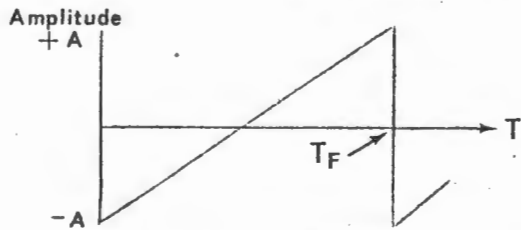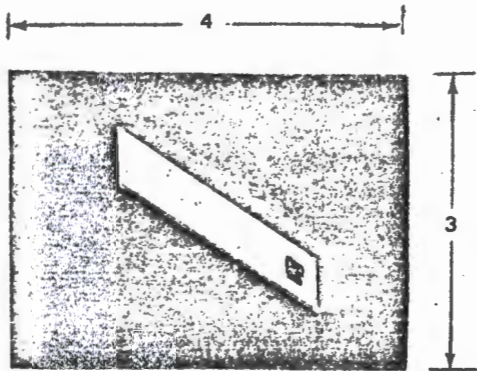
Amplitude
+ A

T_F

T

− A

Direction Of Horizontal Scan

Direction Of
Vertical Scan

4

3

2

1.5

Infinite Depth
(no scans)

2

1.5

Direction Of
Vertical Scan

Direction Of
Horizontal Scan

4

3
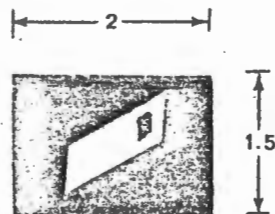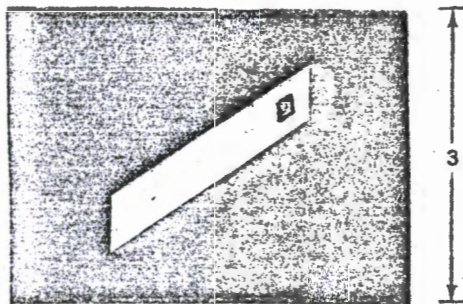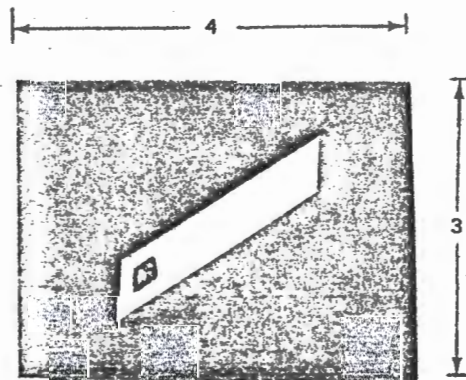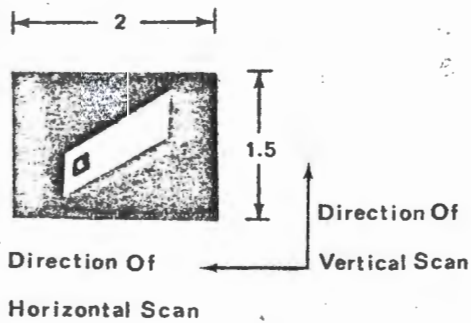
CRT's vertical deflection waveform are varied. In Figure 4-23a the CRT's raster is drawn in the same way and with the same aspect ratio as the raster of the camera. In 4-23b the amplitude of the vertical ramp has been reduced to one half of its initial value; the length of the CRT's raster, consequently, has been reduced by half. This reduction results in an increased aspect ratio and causes the diagonal white area of 4-23b to rise more slowly than it did in 4-23a. In Figure 4-23c the amplitude of the vertical deflection signal has been reduced to zero, and the raster appears to be a horizontal line which is black along the end segments and white in the center.

In Figure 4-23d&e the phase of the vertical ramp causes the raster of the CRT to be drawn from the bottom to the top. Since the camera's raster is drawn from top to bottom, the luminance signal from the top line of the camera's raster controls the intensification of the bottom line of the CRT's raster, etc. Consequently, the image on the CRT is inverted top-to-bottom from the image on the face of the camera tube.

4.2.1.3 Depth Animations

If the width and length animations previously described were to start at the same time and occur at the same rate, a depth animation would result (Figure 4-24--notice how each part of this illustration relates to each corresponding part of Figures 4-22 and 4-23). Since both dimensions change at the same rate, the aspect ratio remains constant during depth animation. The image of Figure 4-24a recedes to an infinite depth at 4-24c and returns to its initial, but inverted, depth at 4-24e.

4.2.1.4 Horizontal Animations

Horizontal animations can be roughly separated into two categories. One category, translations, appears to modify the whole raster uniformly. The other, warps, modifies different parts of the raster in different ways.

4.2.1.4.1 Horizontal Translations

Suppose we are doing an animation that requires an arrow to move in a straight line from the left side of frame to the right side of frame. Suppose also that the length of the arrow must be one half of the horizontal length of the frame and that the arrow must go across frame in one second. *The frame in this case is the area of the CRT's face included in the field of view of the camera (film or SCAN-CONVERTER) which is aimed at the CRT.* The size of the frame on the CRT's face depends on the position of the camera which looks at the CRT. In the following discussion we will assume that the boundaries of the frame are as shown in Figure 4-25.
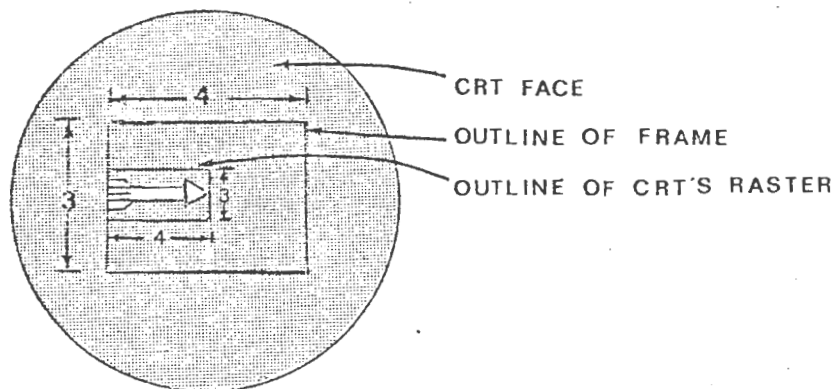
Since the CRT's face is only intensified while the white areas of
the arrow are being drawn, the rest of the raster's area is indis-
tinguishable from any other nonilluminated area of the CRT's face.
The outline of the frame and the CRT's raster would not, therefore,
actually be visible.

The image of an arrow is produced
on the CRT by scanning a transparency of an arrow with one of
Scanimate's artwork cameras and then displaying that camera's output
on the CRT (Figure 4-26). Notice that the arrow's horizontal dimension
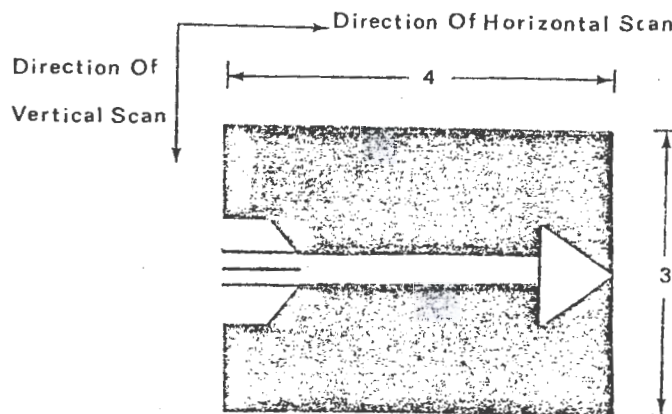
is equal to the width of the CRT's raster. Initially the arrow must
be positioned in the left half of frame (Figure 4-25). The depth of
the CRT's raster must be adjusted to make the arrow the correct width
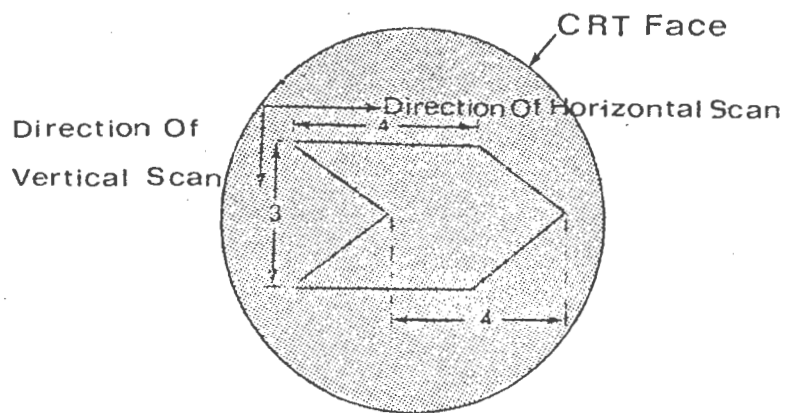while maintaining the raster's 4/3 aspect ratio.

Notice that in Figure 4-25 the
CRT's raster only covers a small part of the face of the CRT and that
the raster is horizontally offset from the CRT's center. To offset
the raster in this manner, a DC voltage must be summed with the hori-
zontal ramp so that the ramp does not go through zero volts. (Remember
that when the horizontal deflection voltage equals zero, the spot
will lie on the vertical line through the center of the CRT's face.

Figure 4-27 shows the type of
horizontal deflection signals required to position the raster (a) in
the left of frame, (b) in the center of frame, and (c) in the right
of frame. For the arrow to move across frame at a constant rate, the
horizontal deflection signal must change linearly from the waveform of
4-27a to the waveform of 4-27c.
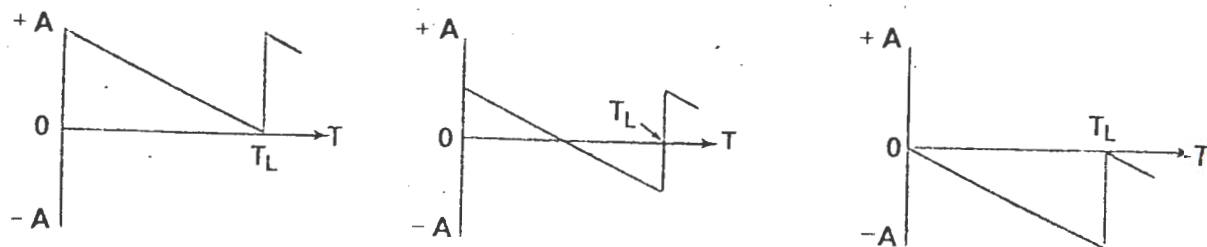
horizontal deflection signal must change linearly from the waveform of
4-27a to the waveform of 4-27c. This linearity will occur if we sum
the horizontal ramp, shown in Figure 4-28a, with the signal shown in
Figure 4-28b.

CRT Face

Direction Of Horizontal Scan

Direction Of Vertical Scan

4

3

4

$\frac{A}{2}$

0

T_L

T

$-\frac{A}{2}$

0

T_F

T

0

$-\frac{A}{2}$
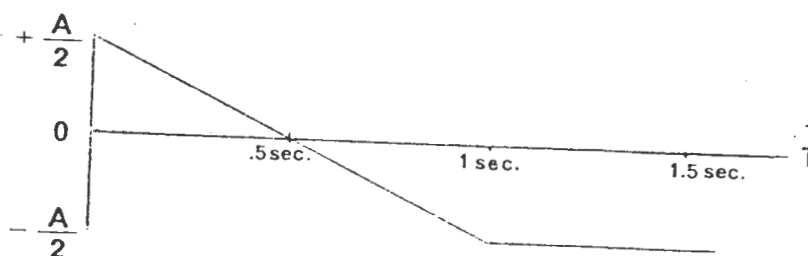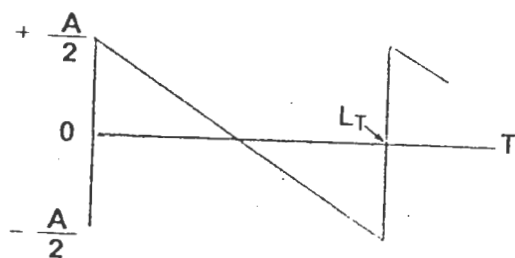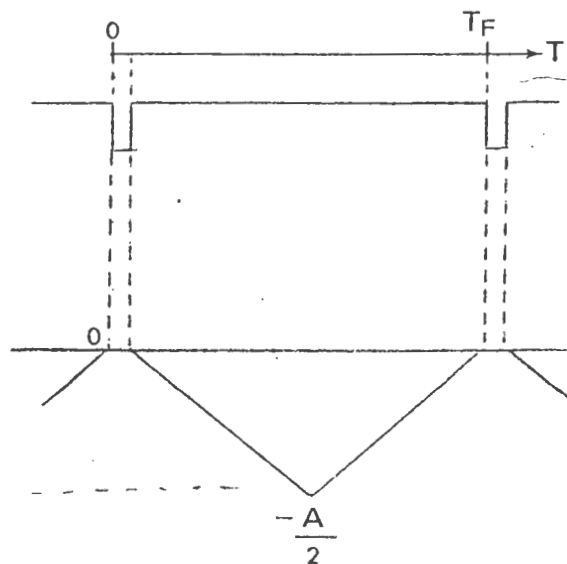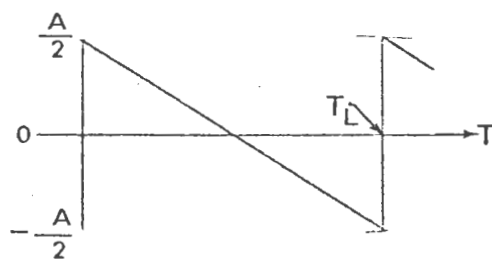
For T < 0 s, the sum of the waveforms of Figure 4-28a&b will yield the waveform of Figure 4-26a. At T = 0.5 s, the sum of the waveforms of 4-28a&b will yield the waveform of 4-26b. For T $\geq$ 1 s, the sum of the waveforms of 4-28a&b will yield the waveform of 4-26c.

Since the period of the ramp in Figure 4-28b is one second, 60 fields will be drawn while the ramp goes from its initial value to its final value. The arrow will be drawn in 60 different positions, therefore, as it moves across the frame. Since the arrow is drawn in so many different positions, its movement will appear smooth and continuous.

Since the amplitude of the one second ramp is continuously changing in such a way as to move the raster from left to right on the CRT's face, each line of a given field will be shifted slightly to the right of the line immediately preceding it. The amplitude of the one second ramp changes very little during the time required to draw one field; the total amount of shift that occurs between any two lines of a field is, consequently, so small that it produces no noticeable distortion of the image on the CRT.

4.2.1.4.2 Horizontal Warps

If the horizontal deflection ramps are summed with a signal whose frequency is a major part of or greater than the field frequency, then the raster of the CRT will be warped. Figure 4-29 is one example of a horizontally warped raster. Notice that all of the horizontal lines are essentially the same length, but each line is offset from the lines adjacent to it.

The raster of Figure 4-29 could be generated from a standard raster on the CRT by adding the triangular waveform of Figure 30b to the CRT's horizontal ramps (Figure 4-30c). The triangular waveform is synchronized with vertical reset (Figure 4-30a) so that it starts each field at zero volts. The frequency is adjusted so that one cycle of the waveform is generated between vertical reset pulses. At the end of each field the triangular waveform is again at zero volts.

Since the triangular waveform
starts and ends the field at zero volts and since its amplitude changes
very little during the time required to draw one horizontal line, the
triangular waveform will have no noticeable effect on the positions of
the first and last lines of the CRT's raster. The triangular waveform
will, however, cause all of the interior lines of the field to be
shifted to the right. The amount that each line will be shifted de-
pends on the amplitude of the triangular wave at the time when each
line is being drawn.

For example, consider what happens
halfway through the field. The triangular waveform is at its negative
peak and its amplitude is equal but opposite to the initial amplitude
of the horizontal ramp. When the peak voltage of the triangular wave
is summed with the horizontal ramp, the resultant is a horizontal ramp
whose amplitude ranges from zero to -A volts. Therefore, the center
line of the field will be the same length as the first and last lines
of the field but will start at a point (the center of the CRT) that
is horizontally displaced one half of a line to the right of the
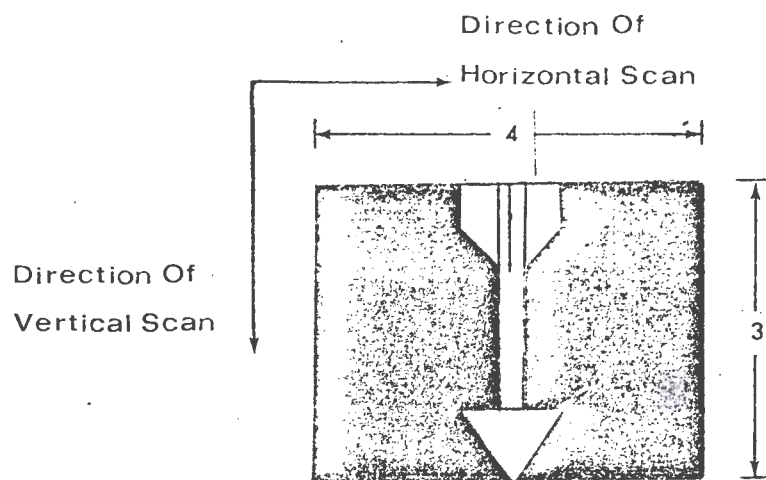starting points of the first and last lines of the field.

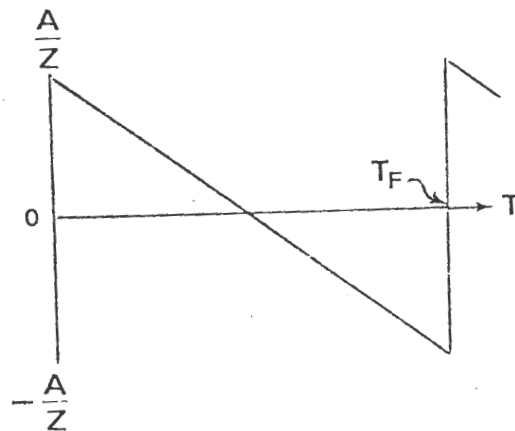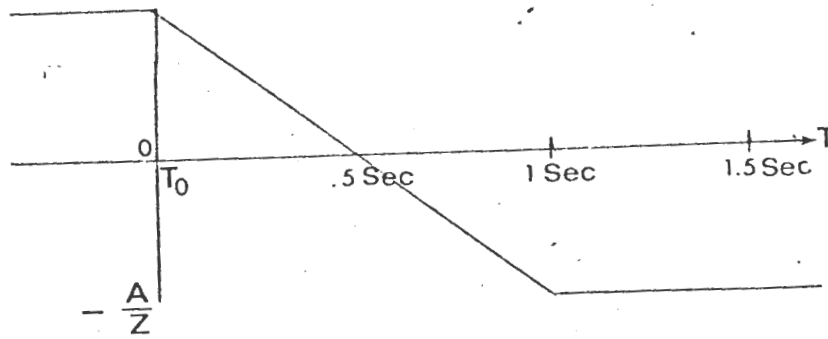#### 4.2.1.5 Vertical Animations

Like horizontal animations, vertical animations
can be either translations or warps.

4.2.1.5.1 Vertical Translations

Vertical translations are produced
by the same types of signals as horizontal translations. The restriction
on the frequency of the animating signal is the same in both cases: The
frequency must be negligible with respect to the field rate for the
raster to be moved as a whole and not appear warped.

Suppose that the artwork of an
arrow is placed under the *ARTWORK CAMERA* to fill the raster of the CRT
as shown in Figure 4-31; suppose also that we want to make the arrow
move from the top to the bottom of frame in one second. Notice that
the arrow's length is the same as the vertical length of the CRT's
raster. If the relationship between the raster and the frame on the

Direction Of
Horizontal Scan

Direction Of
Vertical Scan

4

3

CRT Face

Outline Of The
CRT's Raster

Outline Of Frame

0
T_0
.5 Sec
1 Sec
1.5 Sec
T
$-\dfrac{A}{Z}$

$\dfrac{A}{Z}$
0
T_F
T
$-\dfrac{A}{Z}$
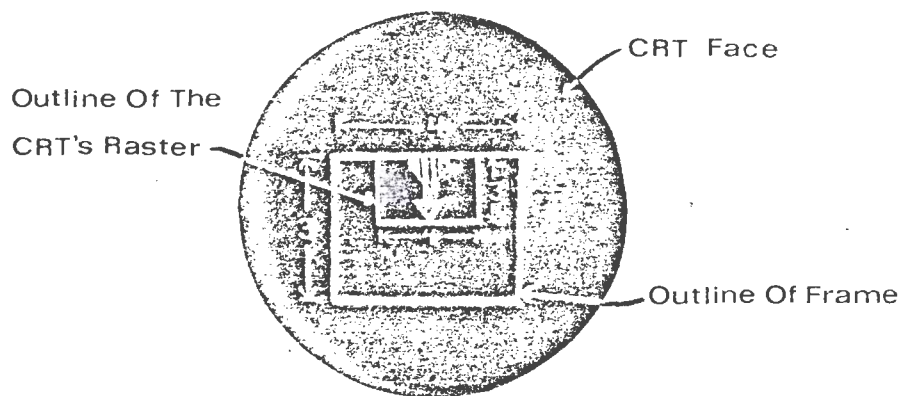
CRT is as shown in Figure 4-32, then the arrow can be given the desired
translation by summing the signal of Figure 4-33a with the vertical
ramp of 4-33b.

The amplitude of the animation
ramp changes in phase with the amplitude of the vertical deflection
ramp. Since these two signals are added together, the amplitude of
the vertical deflection ramp is effectively increased by the amount
that the amplitude of the animation ramp changes during each field.
The increased amplitude of the vertical deflection ramp causes a com-
mensurate increase in the length of the display. Due to the low
frequency of the translating signal, its amplitude changes very little
during any given field; consequently, the vertical stretching of the
fields is not noticeable.

4.2.1.5.2 Vertical Warps

Figure 4-34 is an example of a vertically warped raster. It resembles the horizontally warped raster of Figure 4-29 rotated by 90°, but the frequencies required to generate these two rasters are vastly different.
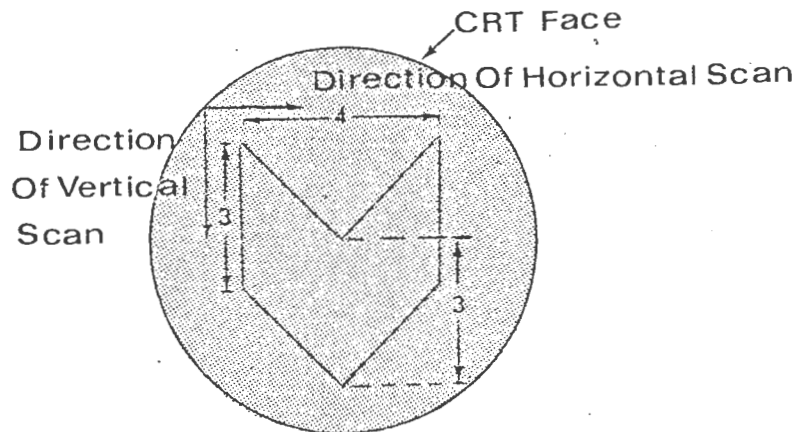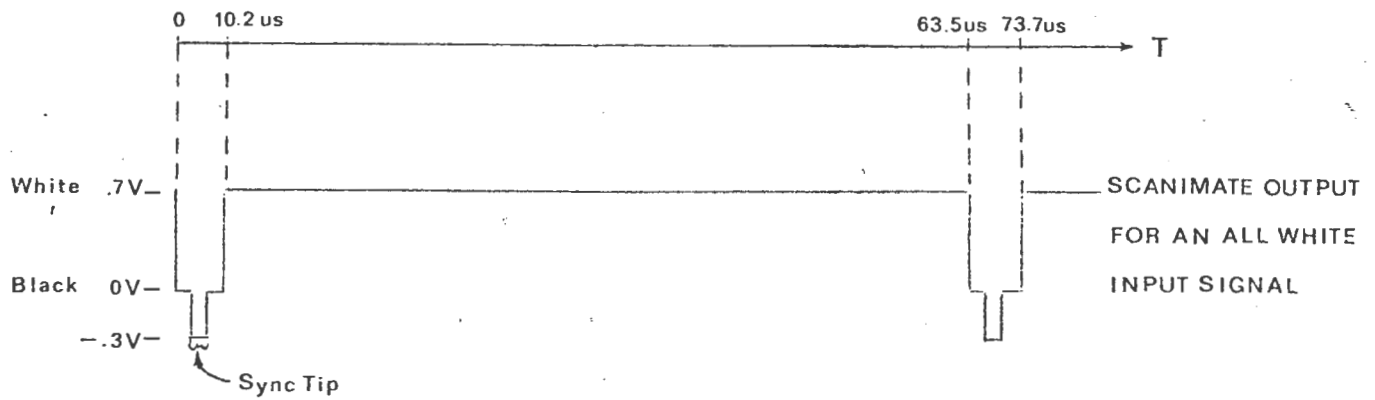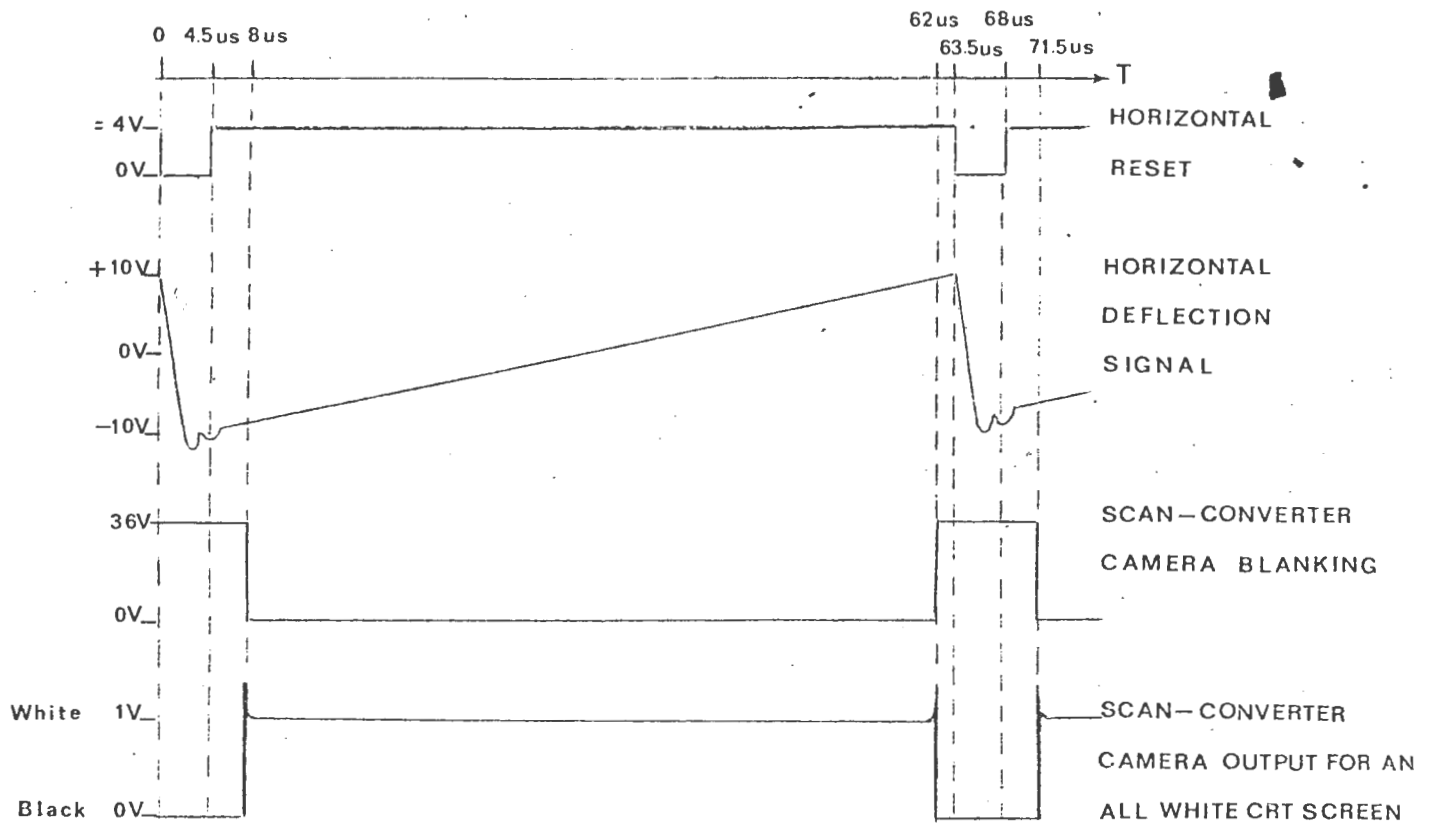

Each horizontal line in the raster of Figure 4-34 is bent into a triangular shape. To generate such a raster, a triangular waveform with a frequency equal to the horizontal line rate (Figure 4-35b) must be summed with the vertical deflection ramp (Figure 4-35c). The triangular waveform is synchronized with the horizontal reset (Figure 4-35a) so that it starts and ends each line at zero amplitude. As a consequence, the vertical positions of the start and end points of each line are determined solely by the amplitude of the vertical ramp, which changes very little during the time required to draw one line. The different vertical positions of the interior points of the lines are determined by the sum of the amplitudes of the vertical ramp and the triangular waveform.
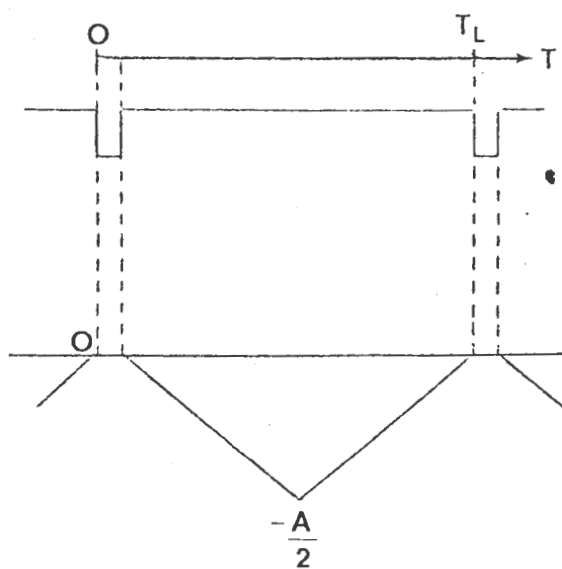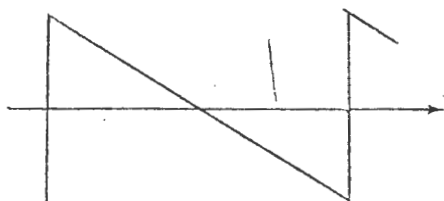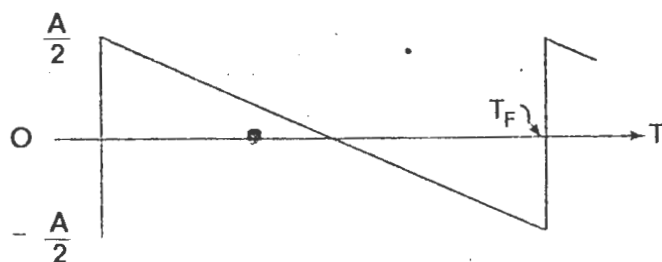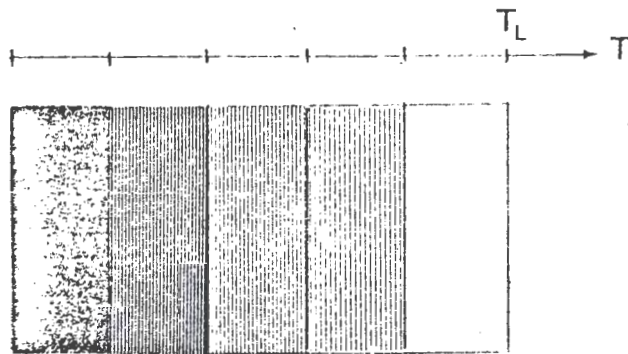
4.3 Conclusion

At this point you should have a general idea of how a television system operates and a sound understanding of what a raster is and of how *Scanimate* produces animation by modifying the raster of the CRT. In the next chapter we will consider the *Scanimate* equipment itself to learn how it is organized for the job of producing animation.
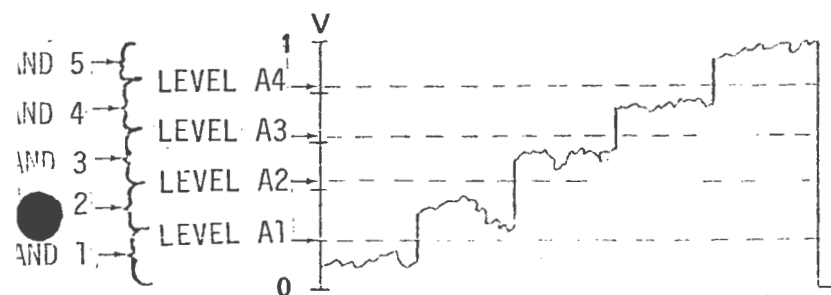
HORIZONTAL RESET

HORIZONTAL DEFLECTION SIGNAL

SCAN—CONVERTER CAMERA BLANKING

SCAN—CONVERTER CAMERA OUTPUT FOR AN ALL WHITE CRT SCREEN

SCANIMATE OUTPUT FOR AN ALL WHITE INPUT SIGNAL

Sync Tip

T_L

$\longrightarrow$ T

GRAY LEVEL CHART AS SEEN BY
THE ARTWORK CAMERA/IMAGE ON
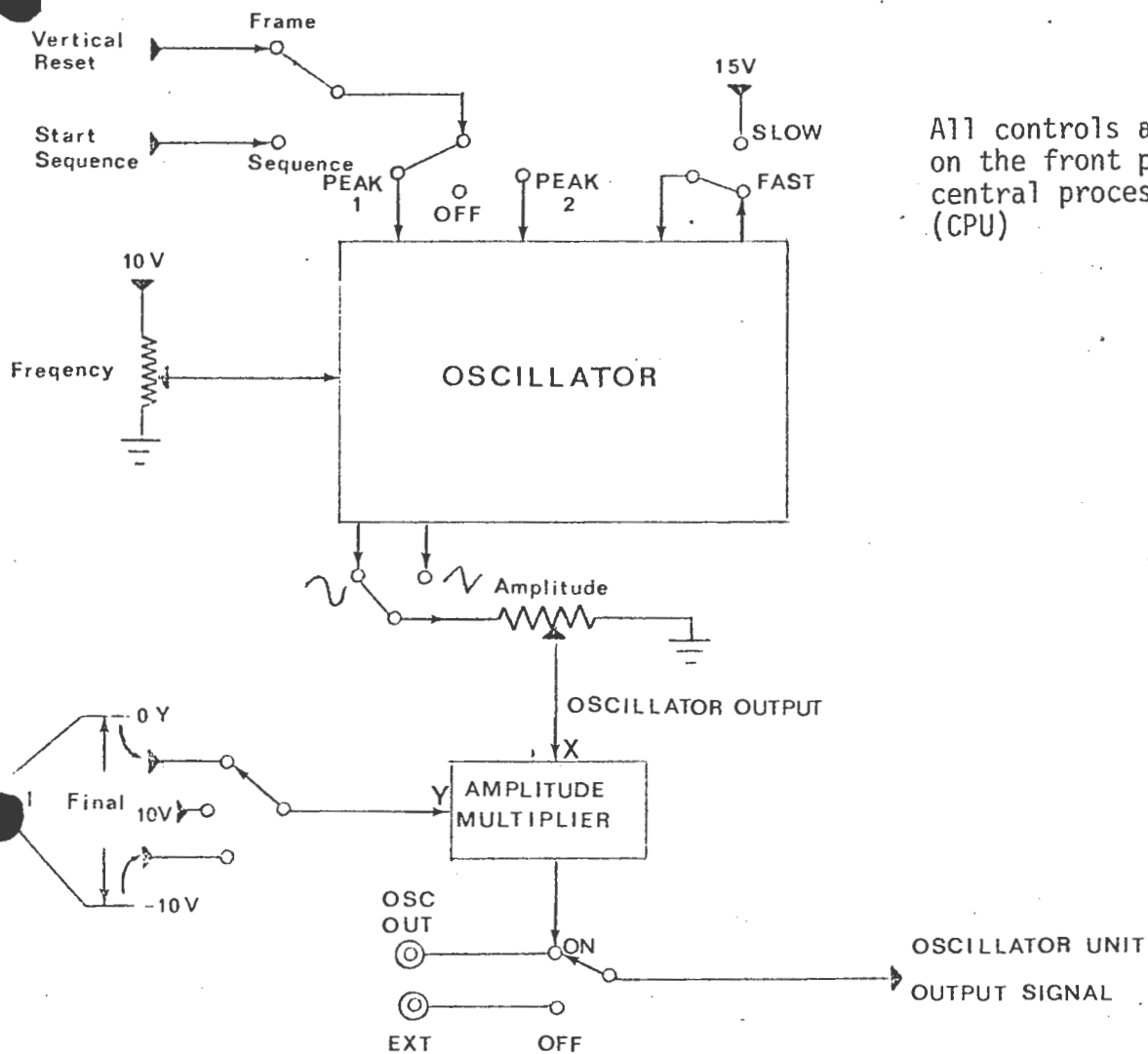THE CRT AS SEEN BY THE SCAN-
CONVERTER CAMERA

% Of Transmitted
Light
100
80
60
40
20
0

THE PERCENTAGES OF LIGHT
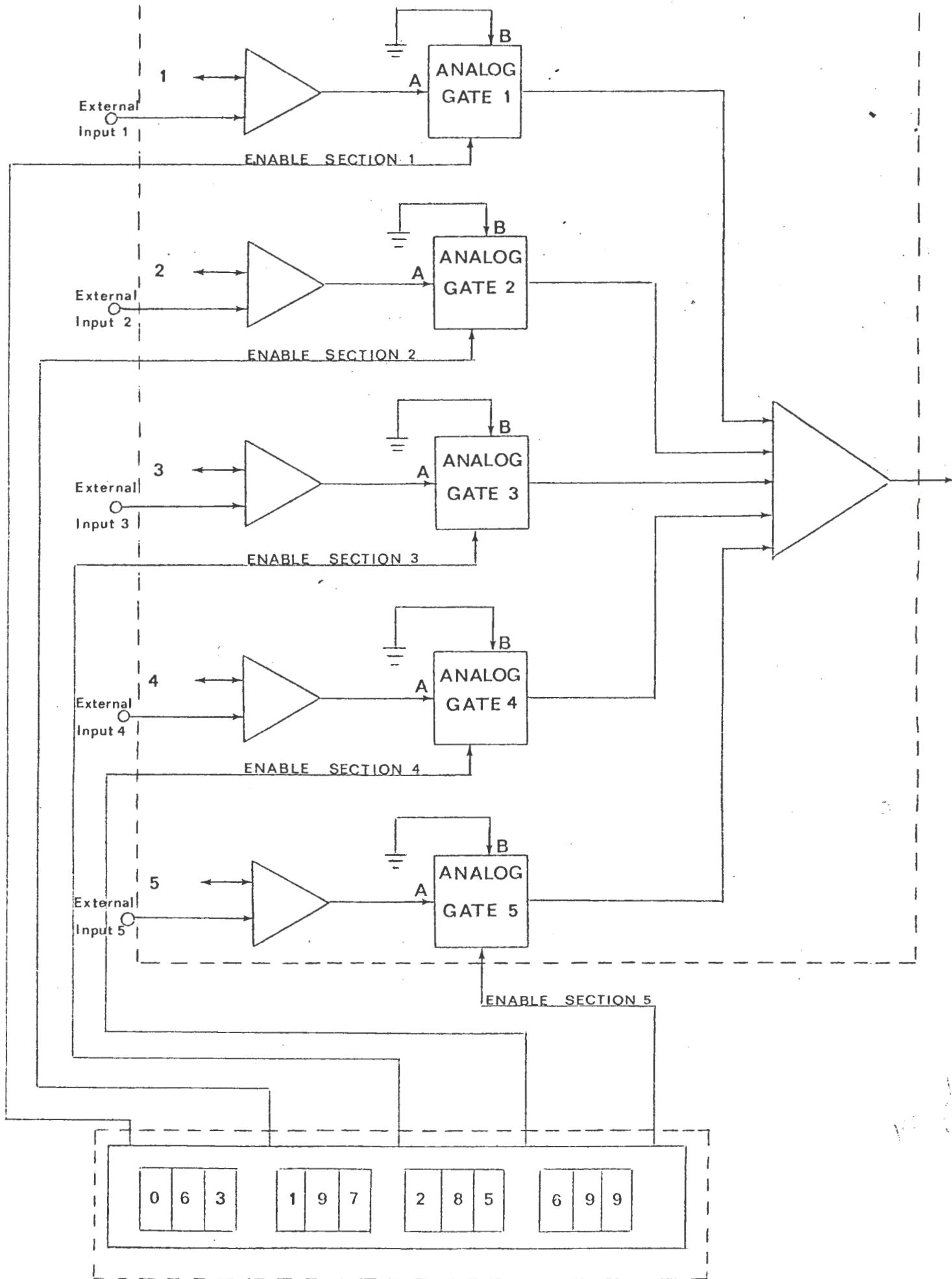TRANSMITTED THROUGH THE
DIFFERENT AREAS OF THE
GRAY SCALE TEST CHART

V
1

ND 5 — LEVEL A4
ND 4 — LEVEL A3
ND 3 — LEVEL A2
2 — LEVEL A1
ND 1 —

0

LUMINANCE SIGNAL OUTPUT FROM
ARTWORK CAMERA A

V
1
.8
.6
.4
.2
0

THE ENCODED LUMINANCE
SIGNAL WHICH GOES TO
THE CRT

Vertical Reset — Frame

Start Sequence — Sequence

PEAK 1 — OFF — PEAK 2 — FAST

15V — SLOW

10 V — Freqency

OSCILLATOR

Amplitude

OSCILLATOR OUTPUT

0 Y — Final — 10V — -10 V

X — Y — AMPLITUDE MULTIPLIER

OSC OUT — EXT — OFF — ON

OSCILLATOR UNIT OUTPUT SIGNAL

All controls are located on the front panel of the central processing unit (CPU)

External Input 1 — 1 — ENABLE SECTION 1 — ANALOG GATE 1 — A — B

External Input 2 — 2 — ENABLE SECTION 2 — ANALOG GATE 2 — A — B

External Input 3 — 3 — ENABLE SECTION 3 — ANALOG GATE 3 — A — B

External Input 4 — 4 — ENABLE SECTION 4 — ANALOG GATE 4 — A — B

External Input 5 — 5 — ENABLE SECTION 5 — ANALOG GATE 5 — A — B

| 0 | 6 | 3 | | 1 | 9 | 7 | | 2 | 8 | 5 | | 6 | 9 | 9 |

V = T

$$V_o = \frac{T^2}{10}$$
$$(V_o = T^2)$$

V (Volts)

V = T

$V_o = \dfrac{T^2}{10}$

$(V_o = T^2)$

T (Sec.)
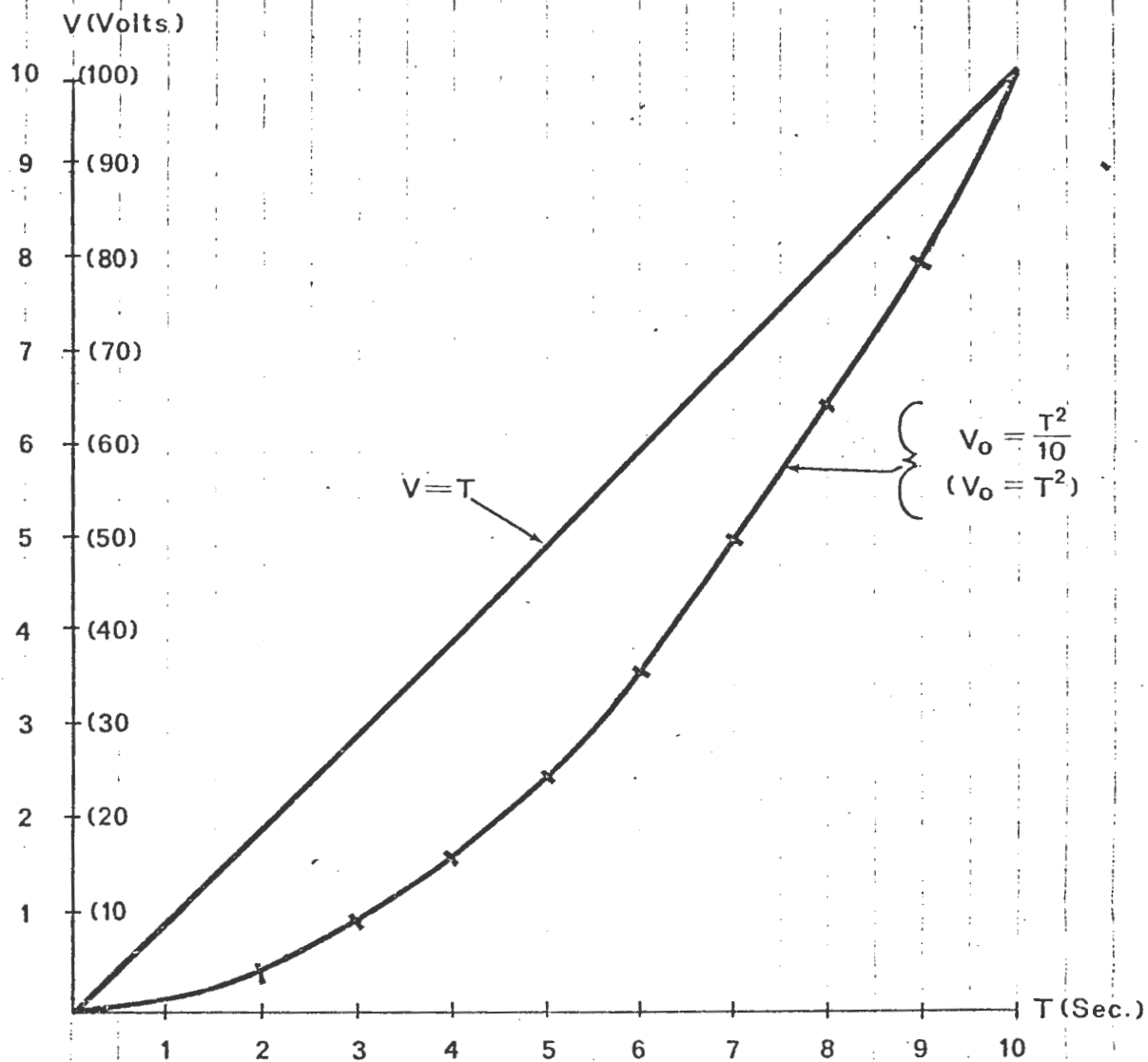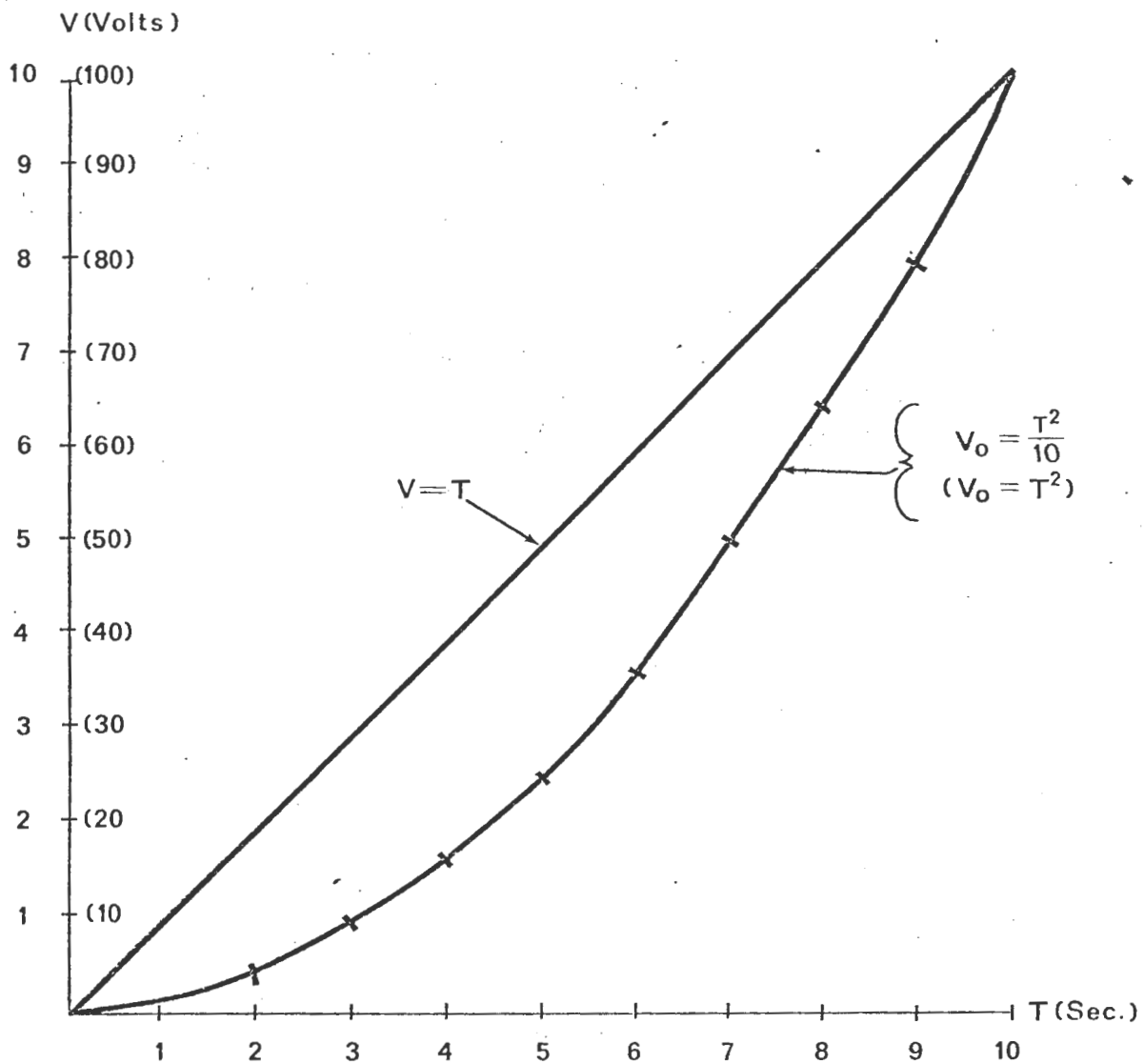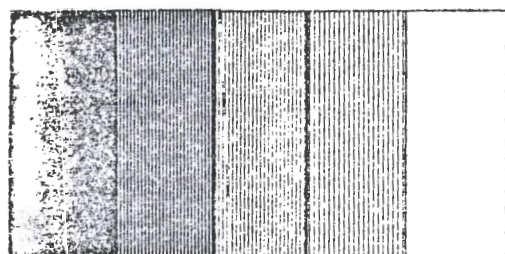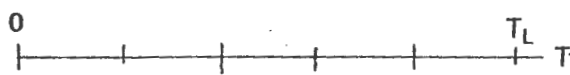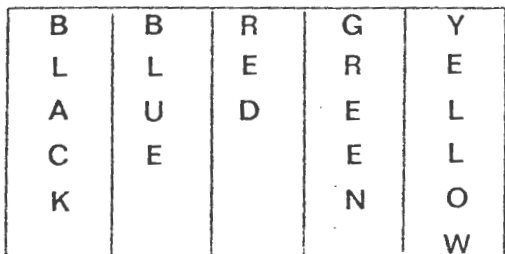
GRAY LEVEL CHART AS SEEN
BY THE SCAN-CONVERTER CAMERA

THE FIVE AMPLITUDE
BANDS ESTABLISHED
IN THE COLORIZER
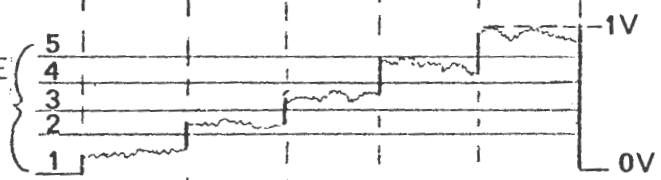
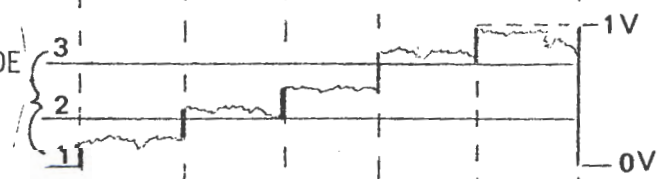LINE RATE LUMINANCE OUTPUT
SIGNAL FROM THE SCAN-CONVERTER
CAMERA DIVIDED INTO FIVE BANDS

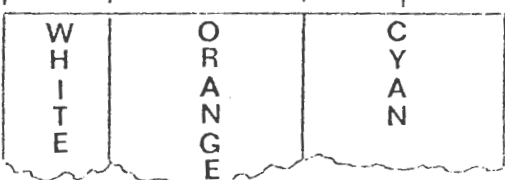OUTPUT OF THE COLORIZER
DISPLAYED ON A COLOR
TELEVISION SET

E THREE AMPLITUDE
NDS ESTABLISHED
THE COLORIZER

LINE RATE LUMINANCE OUTPUT SIGNAL
FROM THE SCAN-CONVERTER CAMERA
DIVIDED INTO THREE BANDS

OUTPUT OF THE COLORIZER
DISPLAYED ON A COLOR
TELEVISION SET

NONCOMPOSITE MIXED LUMINANCE SIGNAL

COMPOSITE SYNCRONIZATION SIGNAL

COLOR SYNCRONIZATION BURST

CHROMANANCE SIGNAL

COMPOSITE NTSC COLOR SIGNAL